Bombs vs. Battleships

ARMY ORDNANCE

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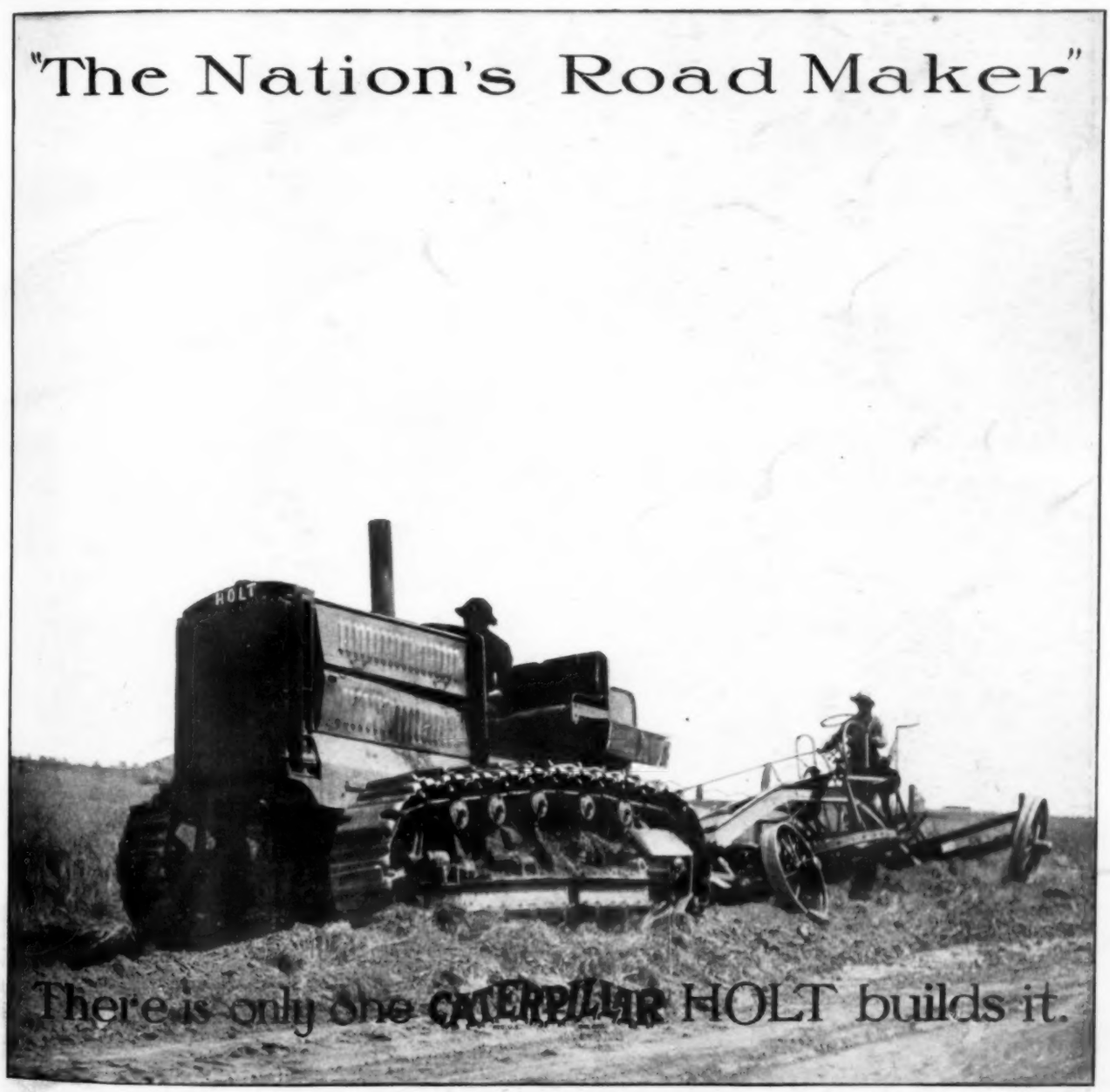
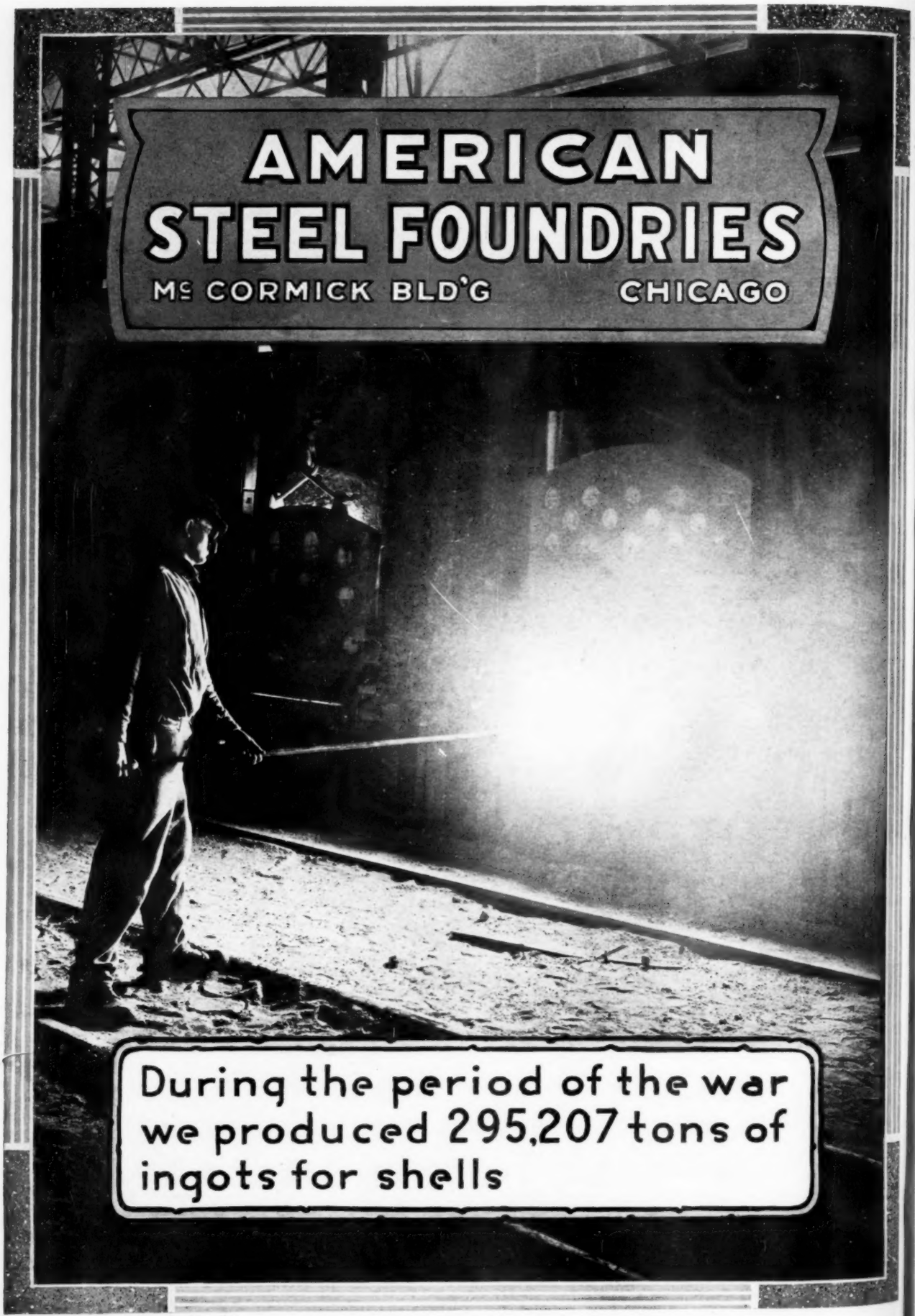


THE JOURNAL OF THE ARMY ORDNANCE ASSOCIATION

Third Annual Meeting, Aberdeen Proving Ground, Md., Friday, October 7, 1921


AMERICAN
STEEL FOUNDRIES
Mc CORMICK BLD'G CHICAGO
During the period of the war
we produced 295,207 tons of
ingots for shells

ARMY ORDNANCE

THE JOURNAL OF THE ARMY ORDNANCE ASSOCIATION

Pledged to Public Service in Effecting Industrial Preparedness for War as Our Strongest Guarantee of Peace

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VOL. II. SEPTEMBER-OCTOBER, 1921 No. 8

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WAR DEPARTMENT
OFFICE OF THE CHIEF OF AIR SERVICE
WASHINGTON

July 30, 1921.

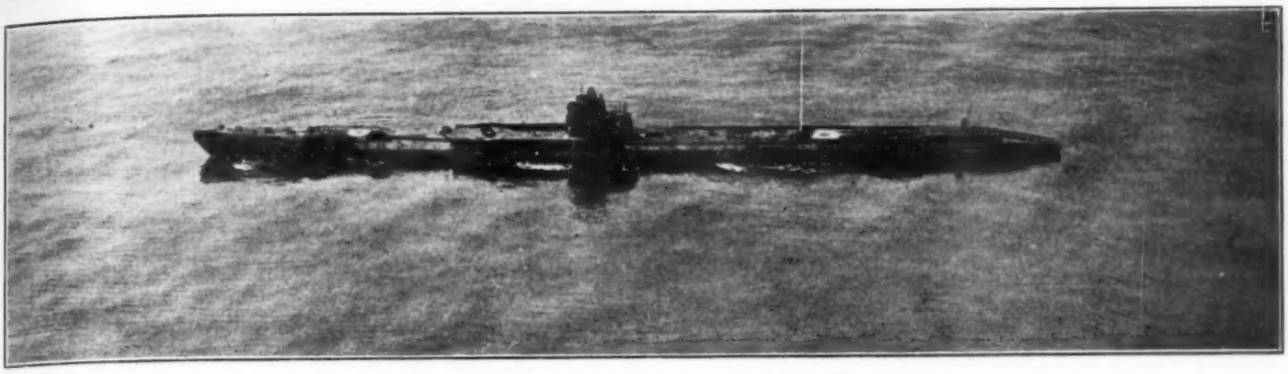
From: The Chief of Air Service.
To: The Chief of Ordnance.
Subject: Appreciation.

1. It is impossible to review the successful results achieved by the Air Service in the recent bombing tests off Chesapeake Bay without being tremendously impressed with the exceedingly important part played by the Army Ordnance Department in the attainment of that success. In every phase of the complicated problem presented, the Ordnance Department has given that wholesouled co-operation, coupled with enthusiasm and efficiency so vital to the successful termination of such an important undertaking.

2. As a technical service, the Air Service appreciates to the full the difficulties attendant upon a development and production program such as it has been necessary to carry out to produce the complicated efficiently functioning mechanisms without which, instead of a glorious success, there might have resulted a disastrous failure. In a field so new there were many setbacks and discouragements, which, even had there been no time limit, would have been extremely serious. Considering the exceedingly short period of time allowed by the problem the results achieved by your Department stand out, as indeed, remarkable.

3. Again may I express to you on the part of the Air Service the deepest appreciation of the efforts of yourself and your entire organization. On behalf of the Air Service, will you also express to the personnel expressly concerned with the perfection of certain of the details of the problem, my commendation for their untiring and efficient labor which has produced a weapon which may revolutionize our system of National Defense. In this connection I have especially in mind Maj. Wm. A. Borden, Capt. C. H. M. Roberts, and Mr. A. J. Bohrer, all of the Aircraft Armament Division. Also to Capt. S. R. Stribling, Mr. F. V. Ludden, Mr. Joseph P. Collins, Mr. George Bertram, and Mr. Charles E. Hildebrand of the Technical Staff; to Lt. Col. Harry B. Jordan, Maj. C. A. Waldmann, Maj. T. Whelen, Maj. J. H. Woodberry and Mr. D. L. Woodberry, concerned directly in the manufacture of the bombs and fuses; to Maj. F. H. Miles, Jr., and Mr. Seavy who were responsible for the loading of the bombs and fuses; and to Maj. H. C. Davis, Maj. J. H. Hunter, Mr. F. Hawkes and Dr. C. G. Storm of the Ammunition Division.

CHAS. T. MENOHER,
Major General, U. S. A.,
Chief of Air Service.



Ex-German Submarine "U-117," Sunk by Naval Bombing Aircraft on June 21

Bombs *vs.* Battleships

By

C. H. M. ROBERTS*
Member A. O. A.

THE recent bombing tests carried out by the Army and Navy Air Service, using as their targets some of the ex-German naval vessels, have been the occasion of much comment and criticism, both adverse and favorable. The purpose of this article is not to join forces with either party to the argument, but rather to discuss the purpose and results of the tests and to comment upon the performance of the bombs employed.

Briefly, the purpose of the tests was to determine the vulnerability of naval vessels to bombing attacks by airplanes. In addition, the ability of land planes to proceed considerable distances to sea, carrying heavy bomb loads, to discharge those loads effectively against a target and return safely to a land base was to be demonstrated.

The targets chosen for the bombing maneuvers comprised the four principal types of war vessels: (1) the submarine, (2) the destroyer, (3) the cruiser and (4) the battleship. The ex-German vessels *U-117*, *G-102*, *Frankfort* and *Ostfriesland* represented, respectively, these four classes of war vessels. In addition, the ex-U. S. battleship *Iowa*, steaming at sea under radio control, was to be used to demonstrate the ability of airplanes to discover and effectively bomb a ship at sea and capable of being maneuvered to avoid attack. None of the targets were to be equipped for anti-aircraft defense. The targets, with the exception of the *Iowa*, were anchored in deep water, approximately 70 miles east of Cape Charles, Va.

The submarine *U-117* was commissioned in 1918, and had a surface displacement of 1,160 tons. She was 267 feet long, beam 24 feet and draft of 13 feet. Her armament consisted of 4 torpedo tubes, one 4-inch gun and 4 mine-laying tubes. This submarine is reputed to be the vessel which operated for a time off the Atlantic coast of the United States during 1917.

The destroyer *G-102* was an Argentine vessel, appropriated by the Germans at the outbreak of the war and commissioned in 1914. Her displacement was 1,460 tons, length 312 feet, beam 30 feet, mean draught 9 feet. Her armament consisted of four 4.1-inch guns, 1 anti-aircraft gun and 6 torpedo tubes. She was designed for a speed of 32 knots.

AIR SERVICE RADIOGRAM
VIA BOLLING FIELD RADIO

July 23, 1921.

Langley Field, Va., 10:00 A. M.

To: Maj. Gen. C. C. Williams,
Chief of Ordnance,
Washington, D. C.

Congratulations on excellent work in developing the finest bombs in the world. Without the assistance and co-operation of yourself and your officers our complete success in sinking every ship could not have been achieved. I cannot commend too highly Major Borden, Captain Roberts,* Captain Stribling, and Mr. Moser. They have done wonderful work. Let us continue developments, we are on the right track.

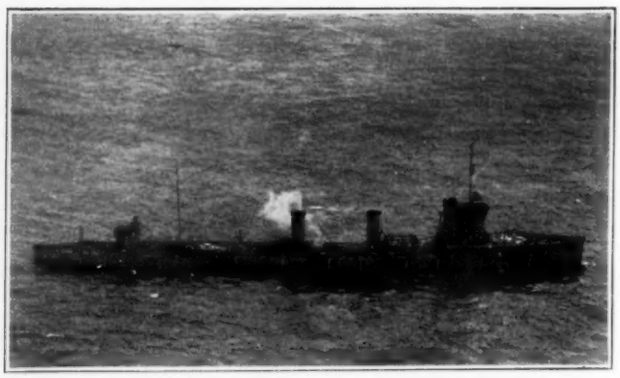
MITCHELL,
Brigadier General, Air Service,
Assistant Chief.

The light cruiser *Frankfort*, completed in March, 1915, was 465 feet long, 45½ foot beam and drew 17 feet of water. Her displacement was 5,120 tons. She was equipped with eight 5.9-inch guns, 2 anti-aircraft guns and 4 torpedo tubes. In addition, she was able to carry 120 mines. This vessel was designed for 28 knots, but it is said that this speed was exceeded in her trials. The *Frankfort* participated in the Battle of Jutland and, after the armistice, was sunk by her crew at Scapa Flow. She was raised, put in condition and delivered to the United States under the terms of the armistice.

The *Ostfriesland* was a 23,000-ton dreadnaught, completed in September, 1909. Her dimensions were: length 546 feet, beam 93 feet, mean draught 27 feet. She was equipped with twelve 12-inch guns in her main batteries, 14 5.9-inch guns in secondary batteries, 4 anti-aircraft guns, and 6 torpedo tubes. Her maximum speed was approximately 21 knots.

The ex-German submarine *U-117* was the target in the first attack, on June 21, 1921, and was sunk in sixteen

minutes with a total expenditure of twelve 170-pound bombs. The honors in this phase of the tests went to the Naval Air Service, as three F-5-L seaplanes, carrying Navy bombs, destroyed the target. On the first run over the submarine one bomb was dropped by each plane as a sighting shot. These bombs dropped quite close to the target and probably caused some damage to the hull. The remaining nine bombs were dropped in salvo on the second run over the target. One direct hit and eight bombs close alongside were the result. The submarine immediately began to sink by the bow, and in nine minutes had disappeared below the surface, leaving only a few bits of wreckage and widening patches of oil to mark the spot where it had been. The speed with which the submarine went under gave no opportunity for an examination by the board of observers to determine the extent of the damage. The un-



Bombing "G102." Direct Hit of Army 25-lb. Bomb

official opinion was, however, that the sinking was due to the opening of seams in the hull by the detonation of bombs under water, close alongside.

The second phase of the maneuvers was the bombing of the ex-*Iowa*, while steaming toward shore under radio control. This part of the program was also carried out by planes of the Naval Air Service, assisted by Army Air Service dirigibles. The problem was divided into two distinct parts, the first being to locate the target, the second to attack it with dummy bombs. The sinking of the *Iowa* was not the object of the attack, and for this reason dummy bombs were used.

The exercise was originally scheduled to take place on June 28, but owing to heavy fog and unfavorable weather conditions was postponed until the following day.

The *Iowa* was reported to be from 50 to 100 miles off shore, between Cape Hatteras and Cape Henlopen, and proceeding toward the coast. The area in which the *Iowa* was to be found comprised nearly 25,000 square miles. The search for the target was conducted by Army dirigibles and Navy seaplanes. One of the dirigibles located the *Iowa* in somewhat less than two hours after the zero hour and communicated its position by radio to the bombing planes. These immediately began to converge on the target and started bombing about 10:30 a. m. Between this hour and 1:30 p. m. approximately 80 bombs were dropped from an altitude of 4,000 feet. During the bombing the *Iowa* was maneuvered on an erratic course with perfect success, the control ship, the U. S. S. *Ohio*, being several miles from the *Iowa*. Of the total number of bombs dropped, but two direct hits were made. The best bombing of the day was done by a formation of five Navy Martin bombers, the bombs being dropped in salvo and making a beautiful pattern around the *Iowa*. Had these bombs been "live" it is likely that serious damage to the ship would have resulted.

The third phase of the tests was the attack of the ex-German destroyer *G-102* by Army bombers on July 13, 1921. This attack was probably the most spectacular of the entire series. The heavy bombers were preceded by a formation of SE-5 pursuit planes, each carrying four 25-pound fragmentation bombs. These planes, with barely enough fuel capacity to accomplish their mission, flew more than 80 miles to sea through intermittent rain squalls and fog banks for the purpose of attacking the target to "neutralize" anti-aircraft fire and create a diversion in order to permit the undisturbed approach of the bombing planes. This mission was most successfully accomplished. The pursuit planes approached in column, successively diving on the target to simulate machine-gun fire. When about 200 feet over the destroyer they levelled off and released their fragmentation bombs. Of 44 bombs dropped, 21 found the target, exploding with a burst of flame and showering the ship with fragments which would have created havoc among personnel above decks. These bombs did little damage to the vessel, which was not a surprise to any one familiar with this type of bomb. Its specific function is the attack of personnel in the open, and its small explosive charge and instantaneous fuse make it ineffective for any other use.

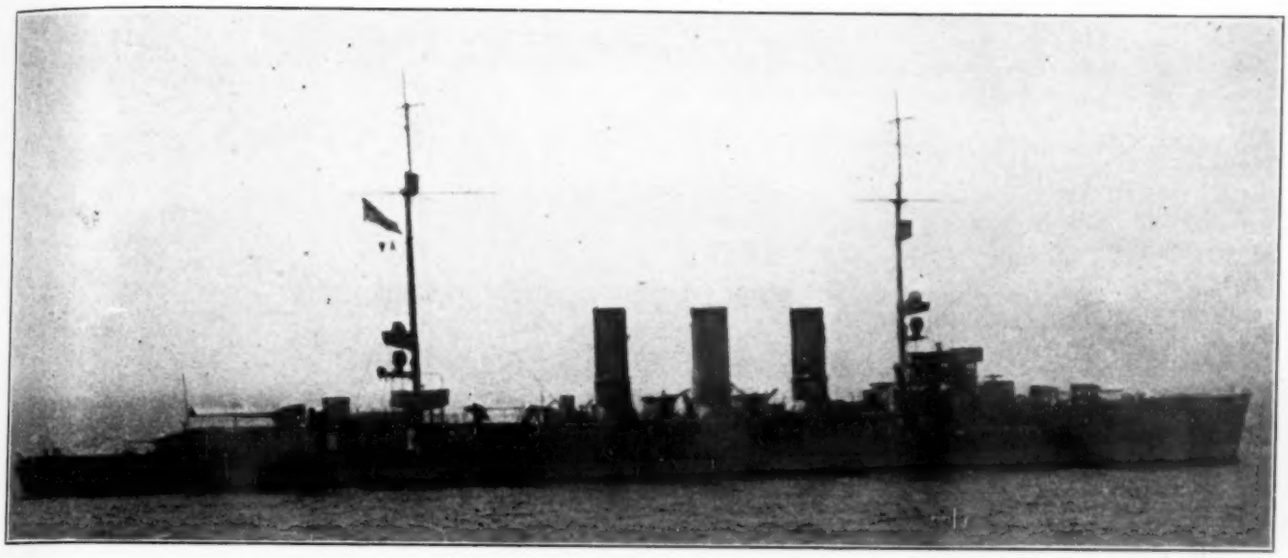
The pursuit planes were followed by a formation of DH-4 B's carrying 100-pound demolition bombs. The attack with these bombs was for the purpose of disabling anti-aircraft guns and control stations, but was discontinued after seven bombs had been dropped to make way for the Martin planes carrying 300-pound demolition bombs.

The Martins appeared from behind the clouds to the northeast, flying in bombing formation at an altitude of 2,000 to 2,500 feet. Two of the first half dozen bombs dropped by these planes found the target and exploded amidship with an ear-splitting report. Black smoke poured out of funnels, hatches and ventilators and fragments of bombs and ship fell into the sea for hundreds of yards around. The destroyer immediately began to settle, and in a short time her decks were awash. The bombing continued, and a few minutes later another direct hit was made, this time between the funnels. The destroyer began to sink rapidly by the bow, and in two minutes had disappeared below the surface.

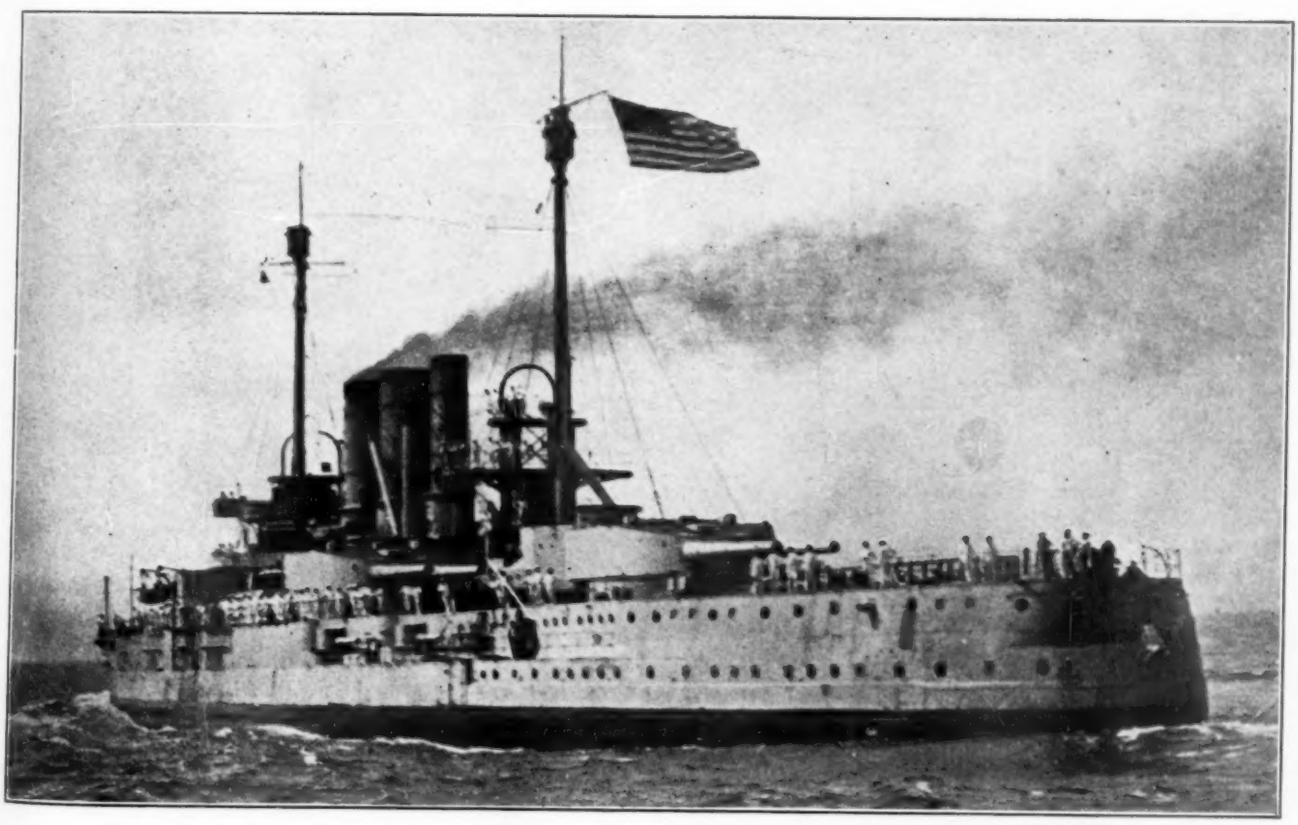
Not content with administering a death blow, the big planes continued to fly across the target dropping bombs all around the destroyer to hasten its end. In all 44 bombs, weighing 300 pounds, were dropped, of which 3 failed to explode, due to being inadvertently dropped "safe." Less than twenty minutes passed from the dropping of the first 300-pound bomb until the destroyer sank below the waves. The total elapsed time, from the beginning of the attack by the pursuit planes, was approximately one hour.

The ex-German cruiser *Frankfort* was the next target selected for destruction by airplane bombs. The attack on this vessel was conducted on July 18 under ideal weather conditions, by alternate raids of Army and Navy planes. The attack began at 9 a. m. and terminated at 4:25 p. m. with the sinking of the vessel by direct hits with Army 600-pound bombs.

The first formation of six Navy bombers approached the target about 9 a. m. and dropped 12 250-pound bombs, making one direct hit. No material damage was done. The second formation consisted of two Army bombers carrying 300-pound bombs. Twelve bombs were dropped. No direct hits were made, but a number of bombs fell close along-



Ex-German Scout Cruiser "Frankfort," Sunk by Army Aircraft on July 18



Ex-German Battleship "Ostfriesland," Sunk by Army Aircraft on July 20

side. The third attack was made by three Navy F-5-L's, dropping six 250-pound bombs. No hits were registered. The fourth attack was made by one Army Martin bomber, dropping six 300-pound bombs and making one direct hit.

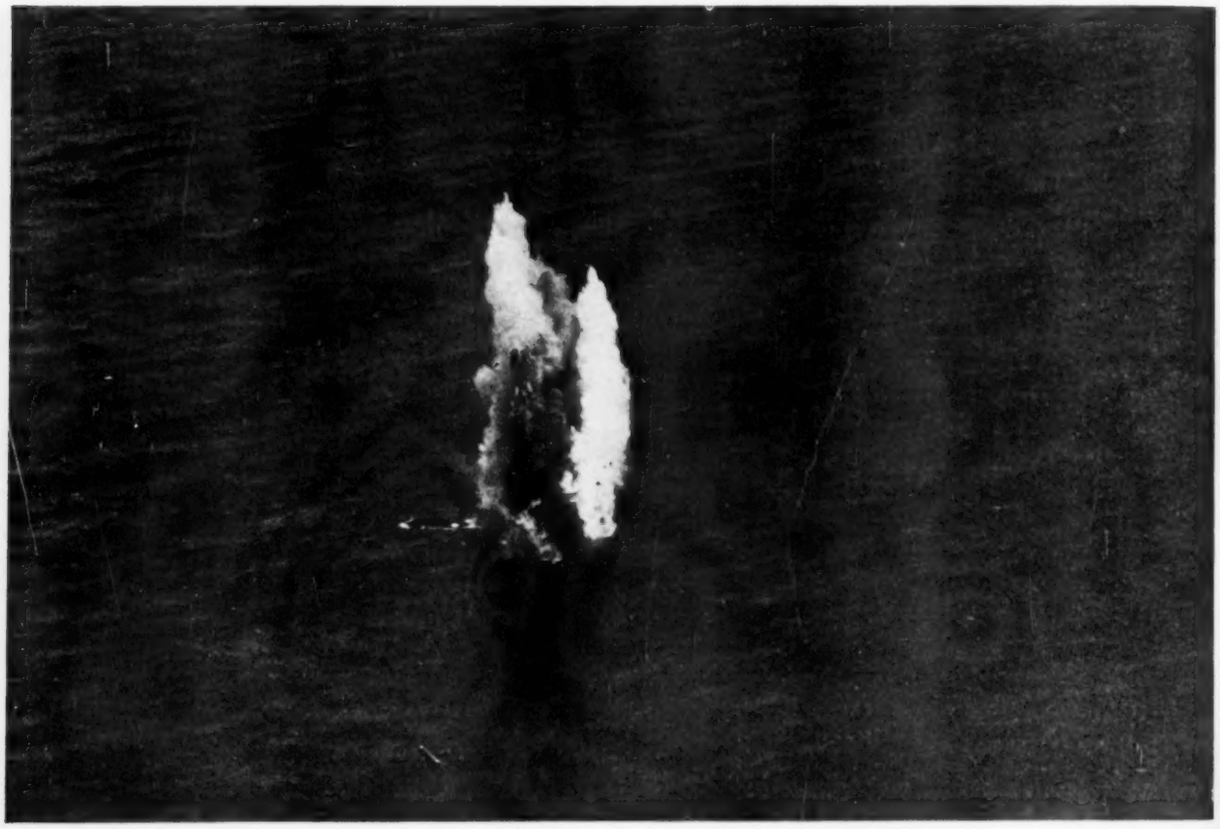
At this stage in the maneuver bombing was halted in order that the official observers might go aboard the *Frankfort* to make an examination. This disclosed the fact that while severe damage had been done to the deck and superstructure of the cruiser, the water-tight integrity of the hull had not been destroyed.

The attack on the *Frankfort* marked the beginning of a second and different phase of the maneuvers against the ex-German vessels. The submarine and destroyer were not equipped with armored protective decks, and hence direct hits with relatively small bombs might be expected to seriously damage or sink them, as was the case. On the other hand, the *Frankfort* and *Ostfriesland* were equipped with such decks, and it was important that the effects of the bombs upon them be determined.

After a complete examination of the *Frankfort*, bombing was resumed by a formation of three Navy F-5-L's, which dropped six 250-pound bombs without scoring a hit. This formation was followed by three Army Martin planes, dropping twelve 300-pound bombs. Again no direct hits were scored, although several bombs from both formations detonated close to the target. These attacks completed the bombing with 250 and 300-pound demolition bombs.

The second phase of the maneuver was conducted with Navy 520-pound bombs and Army 600-pound bombs. Navy Martin bombers made the first and second raids, dropping ten bombs and registering two hits, which contributed to the destruction of the superstructure and decks. While an examination was being made of the effects of these bombs, a formation of six Army Martin bombers arrived and circled the target. They signalled that fuel was limited and they must be allowed to begin bombing within fifteen minutes. The observing party left the target, and as it was not believed that the Army bombs would sink the ship, plans were made to sink her by gun fire and depth charges.

The Army planes began bombing as soon as the "All Clear" signal was given, and dropped fourteen bombs from 3,000 feet. Two direct hits were made, causing the ship to roll violently. One bomb, falling just under the starboard bow, exploded with terrific force, lifting the bow from the water. The starboard bow was crushed in, compartments



Direct Hit of 170-lb. Bomb on the Submarine "U-117"

began to fill, and in less than half an hour she sank, bow first—before the observing party was able to go aboard and determine the extent of the damage. So passed the German light cruiser *Frankfort*, which was completed in 1915 and fought in the Battle of Jutland.

The bombing of the ex-German battleship *Ostfriesland* was carried out on July 20 and 21. Weather conditions on July 20 were most unfavorable and interrupted the maneuvers, which were completed on the following day. It had been planned for Navy planes to drop 250 and 520-pound bombs and Army planes to use 300 and 600-pound bombs before heavy bombs were dropped. These were to be followed with 1,000 and 2,000-pound demolition bombs. However, since the damage to be expected from small demolition bombs had been demonstrated in the attacks on the *Frankfort*, the Army planes using 300-pound bombs were withdrawn from the attack.

Marine Corps DH4 B's, with 250-pound bombs, opened

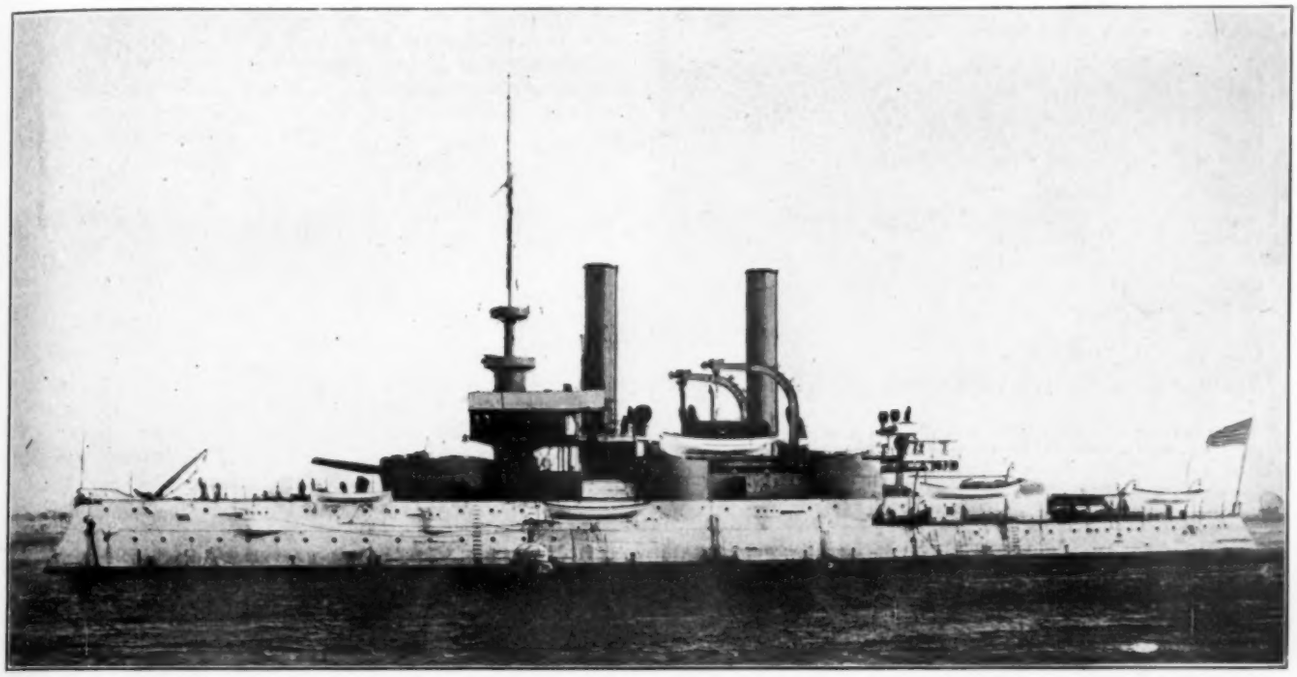
the maneuvers shortly after 1 o'clock, when the weather had cleared sufficiently to make flying practicable. Nine bombs were dropped, with one direct hit. Five bombs were duds. This formation was immediately followed by Naval F-5-L's, which dropped seven bombs. One hit caused local damage, five bombs were duds. A third attack of F-5-L's dropped eleven more 250-pound bombs, of which several were duds. Two bombs just astern probably would have damaged the rudder or propeller had they detonated.

The first formation of Army Martins, carrying 600-pound bombs, then arrived at the target, but were forced to wait nearly an hour while the board of observers made an examination of the battleship. When the attack was begun eleven bombs were dropped, with one hit and five close alongside. It had been seen in the *Frankfort* bombing that direct hits were not as effective as hits in the water close alongside, and consequently the Army bombers tried, with success, to miss the target and hit in the water close to it. All of the bombs detonated and many took effect.

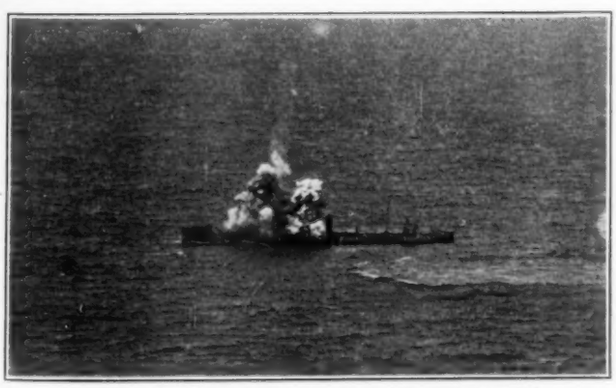
The Army formation was followed by an attack with Navy F-5-L's, dropping twelve 250-pound bombs. Two hits and several duds were registered.

This concluded bombing for the day, and a final examination was made, with the result that no serious damage was discovered. During the night, however, the *Ostfriesland* sank about two feet by the stern, due to water taken in through strained seams. Had the pumps been in operating condition it is likely that this water could have easily been kept out and the ship maintained on an even keel.

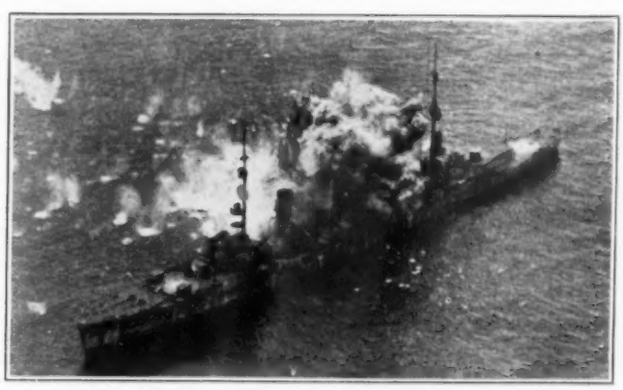
On July 21 flying conditions were much improved over the previous day, and a formation of Army Martin bombers carrying 1,100-pound bombs was sent out to sea. Twelve bombs were carried, but only five were dropped on the target. Of these bombs three were direct hits, exploding with great violence, and the other two were close alongside. Bombing was immediately discontinued in order that an examination might be made, and the planes returned to their base. It was found that the direct hits had caused considerable damage to the decks and superstructure, but that the protective deck was not damaged.



The Radio Controlled Ex-Battleship "Iowa"

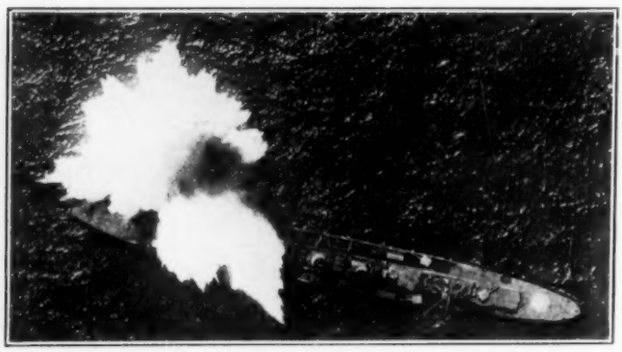


Direct Hit of Army 300-lb. Bomb on Destroyer "G-102"



Direct Hit of Army 300-lb. Bomb on the "Frankfort"

The attack by Army planes with 2,000-pound bombs was then ordered and was delivered shortly after 12 o'clock. Seven 2,000-pound bombs were dropped, the last one exploding under water just after the ship had disappeared from view. The fourth and fifth bombs dropped struck very near the *Ostfriesland's* quarter and stern on the port side. They exploded with terrific force and apparently



Detonation of Army 600-lb. Bomb on Port Bow of "Frankfort"
This is the sort of hit which causes the greatest damage

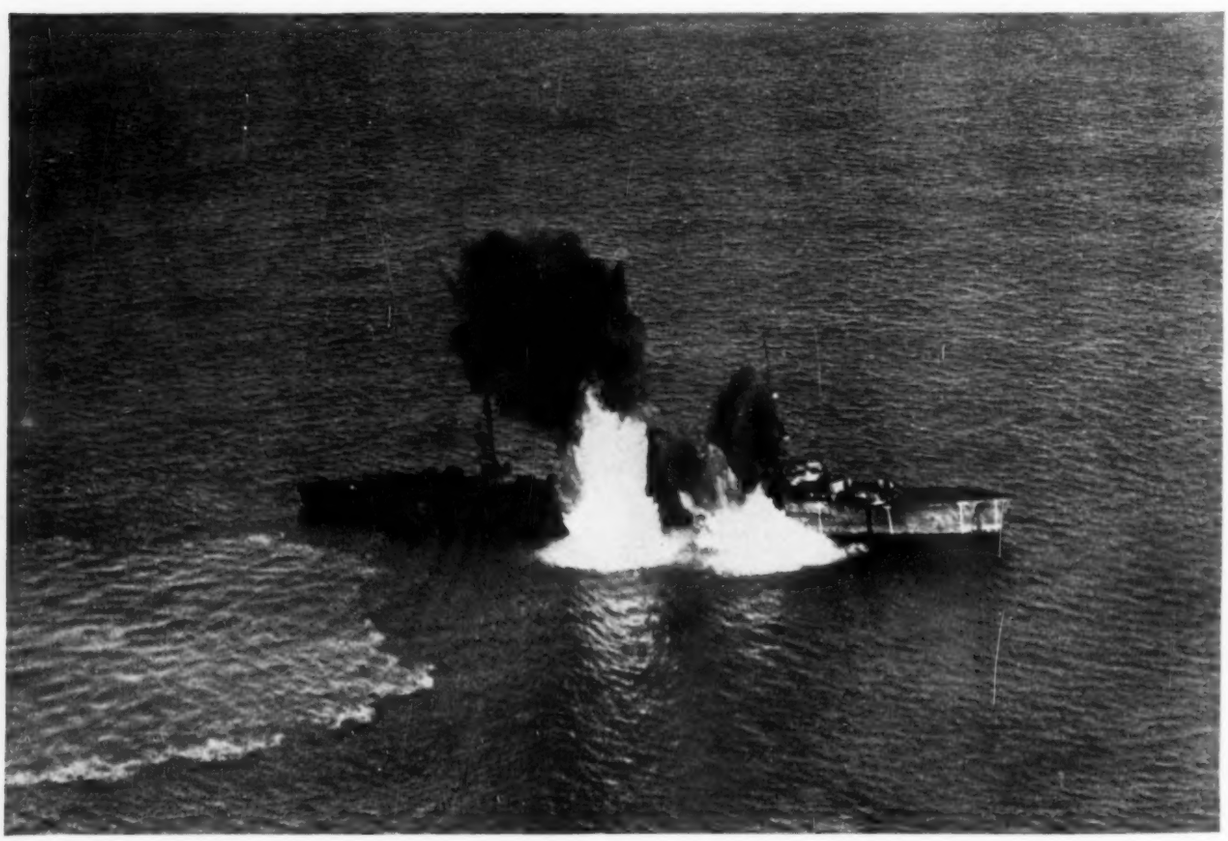
burst in a number of compartments, for the ship immediately began to sink by the stern and roll over to port. In four minutes she had completely turned turtle and sunk stern first. The stern struck bottom before the bow had gone under, and she stood for a moment on end before taking the final plunge to the bottom of the sea. Just before the fatal bombs were dropped one 2,000-pound bomb registered a direct hit on the bow. When the smoke cleared away a great hole could be seen in the starboard side of the forecastle. There was no opportunity to examine the damage done, however, for the next two bombs, dropped almost immediately, gave the ship its death blow.

A distinguished company of high government officials and Army and Navy officers, numbering more than three hundred, witnessed the tests against the *Ostfriesland*. Among them were the Secretaries of War and Navy, Admiral R. E. Coontz, Chief of Naval Operations; General John J. Pershing, Major Generals C. C. Williams, Chief of Ordnance, and C. T. Menoher, Chief of Air Service. Practically every department of the Army and Navy was represented. Brigadier General William Mitchell, Assistant Chief of Air Service, witnessed every test in the series of maneuvers from the air. He flew his DH4B—a land plane—a total of more than sixty hours, practically all of the time at sea, and traversing some six thousand miles.

Aside from the findings of the joint Army and Navy board, which appear below, it may be safely stated that the bombing tests demonstrated the following facts:

1. Present types of demolition bombs are sufficiently powerful to sink battleships of the *Ostfriesland* type, providing a favorable "hit" is obtained.
2. This hit need not be a direct impact on the vessel itself, but may be a delayed detonation alongside, under water.
3. For vessels provided with an armored protective deck a hit alongside with a heavy demolition bomb is apparently more effective than a direct hit on the ship.
4. It is possible for aircraft to find and bomb vessels at sea, proceeding on their course.

The joint Army and Navy Board which witnessed the tests has prepared a report which has been approved by the



Two 600-lb. Army Bombs Hitting alongside the Armored Cruiser "Frankfort"

Secretaries of War and Navy. Their general conclusions are as follows

Joint Board Report on Bombing Exercises

"Within their radius of action, which, relative to that of naval vessels, is extremely short, the effectiveness of heavier-than-air craft carrying large capacity high explosive bombs, depends upon: Ability to locate the naval vessel; ability to hit the target vessel with the projectile carried; ability of the projectile to damage or destroy the vessel. Aircraft of any of the three general classes—lighter-than-air ships, flying boats and land planes—either in combination or singly, have pro-

Cruiser "Frankfort" Sinking as Result of Hits with 600-lb. Army Bombs

nounced ability to search the sea areas within their radii of action and to locate naval vessels operating in such areas. The high speed of aircraft and the range of visibility obtained by altitude are factors which make these craft specially valuable in the Service of Information. Heavier-than-air craft may obtain the maximum radius of action for use in the Service of Information only by carrying additional fuel in place of heavy bombs When armed with heavy bombs the radius of action of heavier-than-air types is inadequate for extensive search operations. Therefore, to conduct an effective attack on naval vessels it will usually be necessary to have certain aircraft for searching and others for conducting the attack with bombs. Darkness, fog, falling or squally weather will greatly reduce the effectiveness of aircraft in search operations. Most of these conditions likewise adversely affect surface vessels conducting such operations, but not to the same extent. The present dependability of the personnel and materiel of the Army and Navy aircraft appears to be such as to insure that search operations, under suitable conditions, can be conducted without an undue percentage of loss. The further development of aircraft will undoubtedly increase both dependability and radius of action.

"The number of dummy bombs which actually hit the target during the experiment with the *ex-Iowa* was a very small percentage of those dropped. Other experiments, however, showed that it is not necessary to make direct hits on naval vessels to put them out of action or to sink them, provided the bombs drop sufficiently close to the vessel and the explosive charge is sufficiently large to produce a mine effect of such proportions as to destroy the water-tight integrity of the vessel beyond the control of its personnel and pumps. The effective target for the bomb being, therefore, greater than the deck area of the target vessel, the percentage of effective bombs would be greater than the percentage of actual hits. Inasmuch as these experiments were not conducted under battle conditions, it is difficult to draw conclusions as to the probability of hitting a target with bombs from aircraft while in action.

"The probability of hitting will be reduced in the case of a target moving at high speed on varying courses; further reduced if the target vessel is protected by effective anti-aircraft armament; and practically negligible if the target is protected by effective pursuit planes. On the other hand, the probability of hitting will be increased by more efficient sighting and bomb-dropping control apparatus, by further training and further development of aerial tactics. In the present state of anti-aircraft defense it is believed that, if an air force can obtain the mastery of the air, an effective percentage of hits can be obtained against surface vessels coming within the radius of action of bombing planes without an undue percentage of loss of aircraft. The effectiveness of the bomb carried by aircraft emphasizes the necessity for the rapid development of anti-aircraft armament and for the provision of pursuit planes as a part of the fleet.

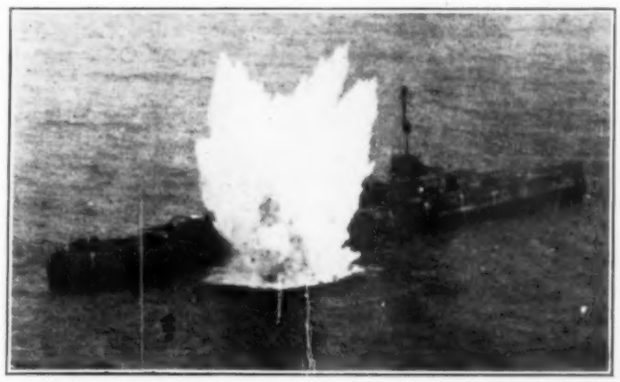
"Aircraft carrying high-capacity, high-explosive bombs of sufficient size have adequate offensive power to sink or seriously damage any naval vessel at present constructed, provided such projectiles can be placed in the water close alongside the vessel. Furthermore, it will be difficult, if not impossible, to build any type of vessel of sufficient strength to withstand the destructive force that can be obtained with the largest bombs that airplanes may be able to carry from shore bases or sheltered harbors. High-capacity, high-explosive bombs hitting the upper works of the vessel are disastrous to exposed personnel, serious to light upper works, comparatively slight to heavy fittings, such as guns, and negligible to turrets. The effect of direct hits was completely local. The most serious effect of bombs is the mining effect when such bombs explode close alongside and below the surface of the water. In the case of major ships the mining effect of a bomb will be materially reduced, due to the ability of the personnel to free the ship of large quantities of water by means of pumps to distribute the excess water through the various compartments and to shore up the water-tight doors and bulkheads which are in most serious danger of carrying away due to water pressure.

"Aircraft, through the medium of machine guns and fragmentation bombs as well as by high explosive bombs of high capacity, possesses sufficient offensive power to seriously threaten the exposed personnel of naval vessels unless such vessels are protected by pursuit planes. This emphasizes the necessity for the further protection of personnel and for the provision of aircraft carriers on which such pursuit planes may be based. The effect of the gas bomb has not been determined, but it is believed that such bombs possess offensive power which, within the radius of action of the aircraft, is to-day a serious threat to vessels insufficiently protected by aircraft.

Summary of General Conclusions

"At present aircraft possesses the following abilities as regards operations with the Fleet in areas beyond the radius of action of aircraft based on shore:

"Limited assistance to gunnery in the control of fire; limited assistance in the Service of Information and Security; important strategical and tactical qualities in operations of coast defense. In adequate quantities they may be the decisive factor in such operations. The availability of these qualities at



Detonation of 600-lb. Army Bomb Alongside the Battleship "Ostfriesland"

present depends largely on weather conditions. The radius of action of bombing planes limits their effectiveness against naval vessels to coast defense, or base defense, in which this type is a very powerful adjunct to the present system of coast defense.

With reference to the effect of aircraft on future naval construction the Joint Board is of the opinion that: (a) The mission of the Navy is to control vital lines of transportation upon the sea. If no opposition is met from enemy naval vessels this mission can be accomplished without entering an enemy's coast zone within which aircraft based on shore or in sheltered harbors are effective. (b) Without an effective navy in time of war a nation must submit to an economic blockade fatal to its trade and the importation of necessary materials for the production of war supplies. (c) If heavier-than-air craft are to be effective in naval warfare, they must have greater mobility, and since their radius of action is not great, additional mo-

bility must be obtained by providing mobile bases—i. e., aircraft carriers. (d) So far as known, no planes large enough to carry a bomb effective against a major ship have been flown from or landed on an airplane carrier at sea. It is probable, however, that future development will make such operations practicable. (e) Even in the present state of development the aircraft carrier, as exemplified by the *Argus* of the British Navy, is a type essential to the highest efficiency of the fleet. (f) Aircraft carriers are subject to attack by vessels carrying guns, torpedoes or bombs, and will require, as all other types of vessels require, the eventual support of the battleship. (g) The battleship is still the backbone of the fleet and the bulwark of the nation's sea defense, and will so remain so long as the safe navigation of the sea for purposes of trade or transportation is vital to success in war. (h) The airplane, like the submarine, destroyer and mine, has added to the dangers to which battleships are exposed, but has not made the battleship obsolete. The battleship still remains the greatest factor of naval strength. (i) The development of aircraft instead of furnishing an economical instrument of war leading to the abolition of the battleship, has but added to the complexity of naval warfare. (j) The aviation and ordnance experiments conducted with the ex-German vessels as targets have proved that it has become imperative as a matter of national defense to provide for the maximum possible development of aviation in both the Army and Navy. They have proved also the necessity for aircraft carriers of the maximum size and speed to supply our Fleet with the offensive and defensive power which aircraft provide, within their radius of action, as an effective adjunct of the fleet. It is likewise essential that effective anti-aircraft armament be developed.

WAR DEPARTMENT
OFFICE OF THE CHIEF OF STAFF
WASHINGTON

July 22, 1921.

From: The Executive Assistant to the Chief of Staff.

To: The Chief of Ordnance.

Subject: Recent Bombing Demonstrations.

The Secretary of War directs me to express to you his satisfaction with the important part played by the Ordnance Department in the recent bombing tests which he witnessed this week near Hampton Roads. He realizes that the construction of fuses for a 2,000-pound projectile is something new to our practice, and noted with great satisfaction that the bombs used by the Army seemed to be entirely reliable. He is very much pleased with the result, and desires that you and your subordinates know it.

J. G. HARBORD,
Major General, General Staff.

The bombs used by the Army Air Service were designed and produced by the Army Ordnance Department. Demolition bombs of 300, 600, 1,100 and 2,000 pounds were employed. These bombs have a T. N. T. content of approximately 50 per cent of the total weight of the bomb and are equipped with delay action fuses which insure their detonation below the surface. Of the total number of demolition bombs of all sizes which were dropped by Army planes, the only failures to detonate occurred when three 300-pound bombs were dropped "safe" on the destroyer *G-102*.

Anti-Aircraft Defense

By

R. L. GOETZENBERGER
Member A. O. A.

MANY have read of the bombing tests off the Virginia Capes, and those of us who reside in Philadelphia have witnessed the theoretical raid which was conducted against that city. These maneuvers have presented an element of fear which has been made more pronounced by those reporters who seem to have forgotten that means of defense against the bombers quite probably would have put another aspect upon their stories.

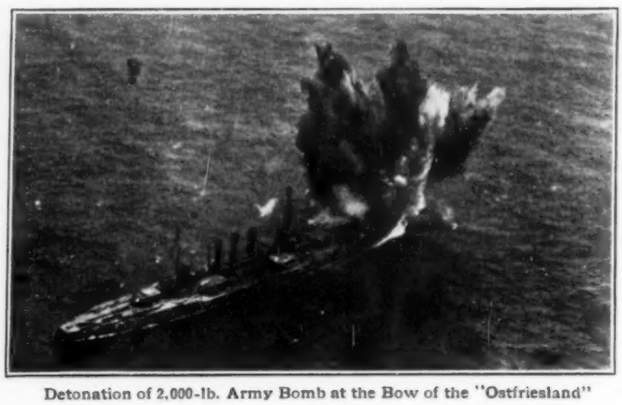
In analyzing the results from a purely technical standpoint, the outstanding features seem to be:

(*a*) The ability of army types of airplanes laden with bombs to fly 100 miles out to sea and to return to their station without a semblance of mishap.

(*b*) The necessity for bombing airplanes and the training of bomb-sight operators.

(*c*) The performance of existing bomb sights as a criterion upon which to base the certain improved results when the stabilized sights have been perfected.

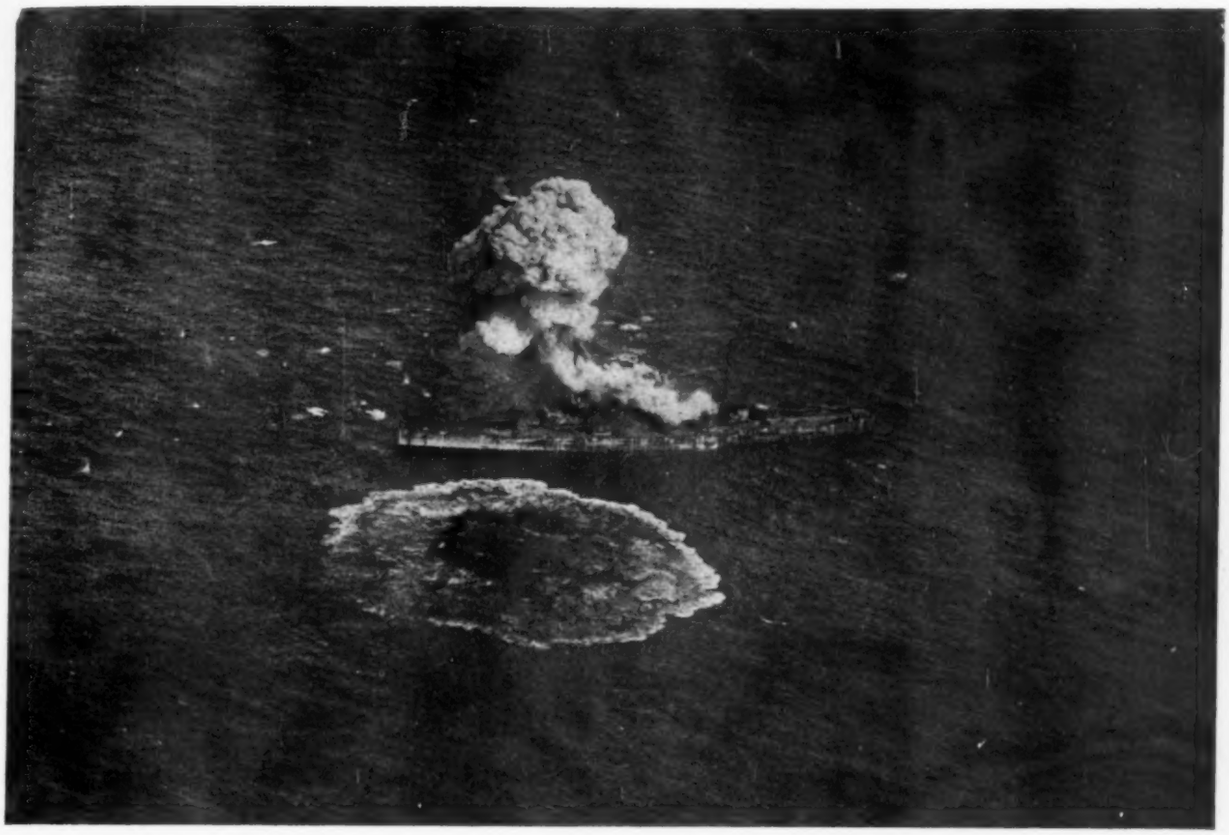
(*d*) The effectiveness of the various capacity bombs and the action of their fuses.



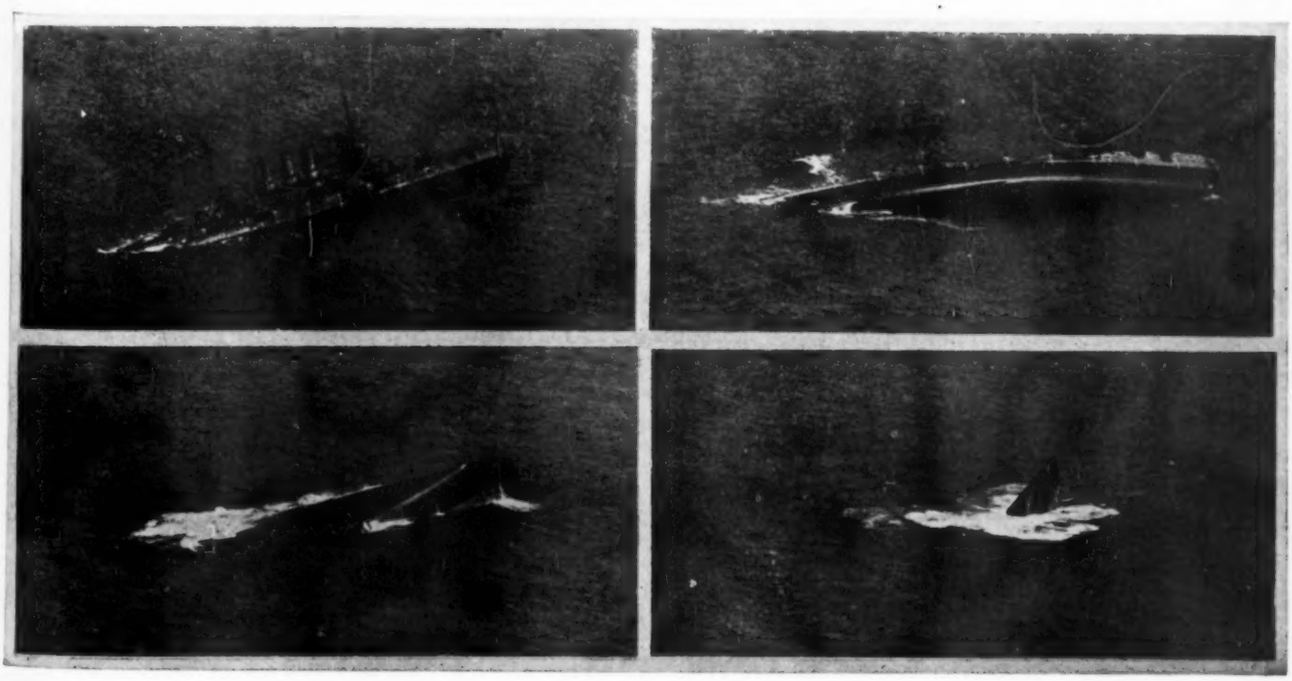
Detonation of 2,000-lb. Army Bomb at the Bow of the "Ostfriesland"

Those persons most qualified to discuss the naval side of the subject have ably shown that the battleship has not become a thing of the past. She has her mission regardless of perfections in aircraft design. But the results do prove conclusively that the airplane is a dangerous weapon and should be given every opportunity for study and production.

What preventative measures against their destruction could have been offered by those boats? Had there been an animate attacking party of some numbers, what defense would have been offered? It would have then been a battle of their airplanes and anti-aircraft guns versus the bombing aircraft. Granted



An 1100-lb. Army Bomb Hitting the "Ostfriesland"



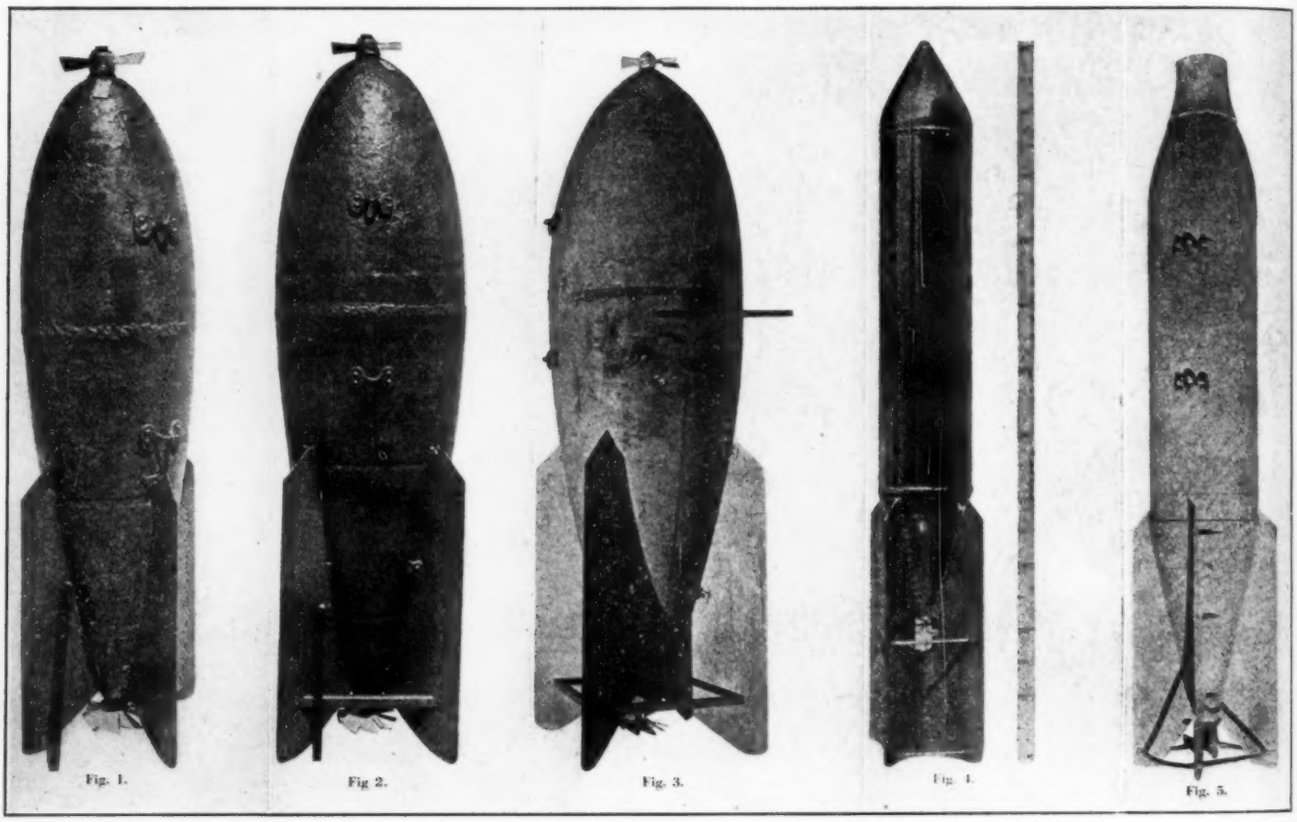
Four Stages in the Sinking of the "Ostfriesland"

that superiority in numbers generally wins battles in the air, and, therefore, that an invading enemy might have lost, there would still have remained other means of defense. In fulfilling its mission, present-day Anti-Aircraft Artillery, with its excellent record during the late war and its advance in design and manufacture of equipment since that time, would have afforded a very efficacious defense.

Reports indicate that the airplanes were flying at heights less than 2,000 feet, and frequently below 1,000 feet, during the actual dropping of the bombs. For this altitude of flying, a few anti-aircraft machine guns of the caliber .30 and caliber .50 type would have set up such a barrage that some, at least, of the aviators would have come to grief and others disturbed in morale before they approached a hitting zone of the ship. Pom-poms, one or two-pounder guns, firing at the rate of about 150 rounds per minute, attaining altitudes above the machine-gun ranges, would have protected the vessels against the higher flying aircraft. Then weapons of calibers 3-inch could have made it uncomfortable for those bombers flying as high as 16,000 feet. It is not inconceivable to apply calibers above 3-inch if needs be.

Undoubtedly tactics would bring the rapidly flying pursuit planes laden with light demolition bombs and equipped with machine guns, as well as chemical weapons, first in combat with the defenses of the vessel. In order to hope to carry on their mission with any degree of success, they must fly low. It is this type of aircraft against which our front-line anti-aircraft machine guns operated so successfully during the recent war. It is therefore not unreasonable to expect a similar effectiveness, perhaps greater since a lesser element of surprise can occur because of all-round visibility at sea. The pompoms would function in a like manner. Probably not more than eight or ten machine guns or pompoms properly located would suffice. The method of sighting these guns would be identical to anti-aircraft practice in the field.

Weapons of 3-inch caliber of latest design could reach airplanes flying at say 1,000 yards above sea level when at as great a distance as 7 miles away from the ship. Besides, they can defend the boat from those nearer airplanes that fly as high as 5 miles in the air. Calibers greater than this, our 4.7-inch A. A. Gun, for example, would increase this defensive zone by approximately 20 per cent. While the sighting of anti-aircraft guns when mounted on board ship does offer some complication, mainly due to the cant effects in high-angle firing, we feel that these difficulties have been very satisfactorily solved. The fire control problem offers no greater complexity than that for batteries firing from land emplacements, provided proper recognition of the methods comparable to those required in controlling the ordinary long-range guns of the battleship is taken. It is even conceivable that greater simplicity can be attained in the case of the control of anti-aircraft armament. Armoring the gun emplacements would insure protection against all, except, perhaps, any unusually well-placed demolition bombs. All fire-control apparatus, with the exception of the observing elements only, could be placed below deck, where ample protection is afforded. The observation elements are light, require little space and few per-



Aircraft Bombs Designed and Manufactured by the Army Ordnance Department for use against Battleships

Fig 1.—300-lb. Demolition; Fig. 2.—600-lb. Demolition; Fig. 3.—1100-lb. Demolition; Fig. 4.—2000-lb. Demolition; Fig. 5.—1100-lb. Armor Piercing

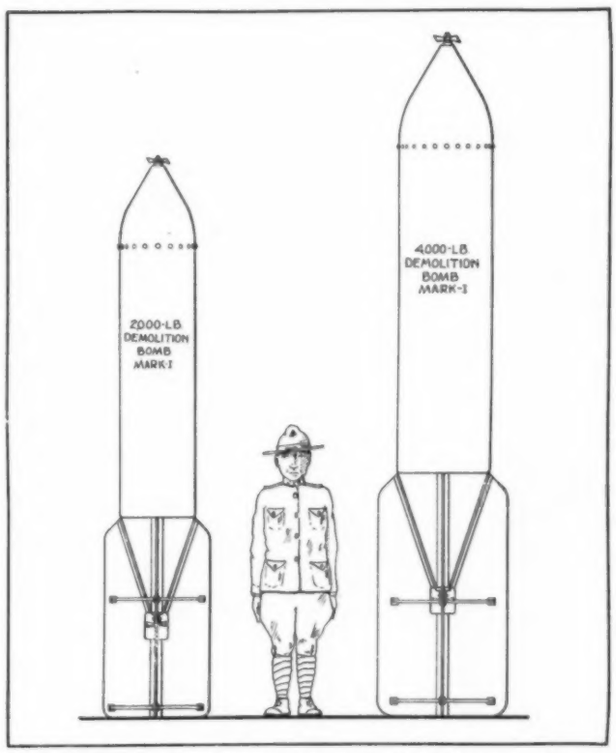
Note: The 1100-lb. Armor-Piercing Bomb was intended to be used against the "Ostfriesland," but was not tested because the ship sank under attack of the 2000-lb. Demolition Bombs

sonnel. If needs be, their position might also be armored. A very acceptable method of fire control, based upon the simple estimation of certain elements of the data, exists. It gives satisfactory results and, for the emergency, does not require instruments.

During days of poor visibility, acoustic devices would be employed instead of sighting elements. These listening apparatus would undoubtedly function as well aboard ship as on land. If night raiding were to be resisted, these devices would form the basic apparatus in conjunction with searchlights to control the firing of the guns.

Passing from the discussion concerning naval defense against aircraft, the writer will undertake to present opinions, based upon his knowledge of the actual measures taken by the larger European metropoles during the war, of the defense of cities by anti-aircraft artillery. As, in the foregoing, the same field of application for machine guns, pompoms and artillery weapons prevails on land. Cities afford larger targets than boats, consequently the raiders generally fly at higher altitudes. Therefore, our discussion need be confined solely to artillery material.

Except during the early stages of the war, no attempt was made to carry on bombing raids of cities in the day time. As anti-aircraft material was perfected and more combat aircraft constructed, it was hopeless to expect to accomplish anything through the perpetration of day raids. The official records of our anti-aircraft artillery in front-line service shows that one airplane was brought down for every 605 rounds of 75-mm. ammunition fired. This record alone is remarkable, but does not indicate the whole measure of the efficiency of our service. They forced many enemy aviators to turn back without accomplishing the mission for which they set out. Also, this firing was principally against the faster-flying aircraft. It would have been reasonable to expect better records if slower-moving bombing planes, such as one would encounter over cities, had been the targets.



Left: 2000-lb. Demolition Bomb Used to Sink "Ostfriesland" compared in size with a six-ft. soldier

Right: 4000-lb. Demolition Bomb Containing one ton of explosive, which will be first tested at the Aberdeen Meeting, Army Ordnance Association, October 7, 1921

The means of anti-aircraft defenses of Paris, London and other principal cities of Europe were passive and active. Under the former classification we have the placing of obstacles, for example, the use of captive balloons whose anchor cables are extended along the most likely routes followed by the raider. Camouflage of scenery is another form of passive defense. The active means comprise a methodical and continuous combat against the raider. It involves the employment of aviation, artillery and searchlights.

Specific reference to the records of the Paris defenses gives an appreciation of the valuable service rendered by anti-aircraft artillery against night bombing raids. The records show that, during 1918, the Germans sent 483 airplanes toward Paris for purposes of bombardment. Of these only 37 succeeded in flying over Paris and 13 of them were brought down by the defenses while attempting to return. This is an excellent record for the defenses considering the size of target Paris offered. Since 1918 the theory of anti-aircraft gunnery and development of material for its usage has advanced appreciably. One could, without doubt, expect much better results nowadays. Further examination of figures shows that only 7½ per cent of the airplanes which took to the air from behind the German lines succeeded in dropping bombs on Paris, and of these 35 per cent were brought down during their return flight.

There is nothing particularly difficult in planning and establishing anti-aircraft defenses of a city, nor is a vast amount of equipment involved. Flying at night, aviators tend to follow courses of streams or railroads as their guides. These determine the locations of the principal defenses. Absolute control by the area commander of certain municipal functions such as lighting, railway and signaling systems, as well as all artillery, listening, searchlight and camouflage posts in and around the city, forms a very effective resistance factor in the defense.

To assume a theoretical destruction of a city such as Philadelphia, whose newspapers have so implied to its readers, without introducing probable anti-aircraft defense into the problem, makes the hypothesis distinctly a one-sided and contestably inconsistent one. Judging then from the advance in the science of anti-aircraft gunnery since the 1918 records of the Paris defenses, it is reasonable to say that less than 5 per cent of the number of airplanes in the raid would have succeeded in flying over Philadelphia, and any damage done would likely have been confined to a few localities.

It is not the object of this article to detract in any way from the success or value of the recent bombing experiences, but rather it is the aim of the writer to present another phase of the problem. With the advance in aircraft performances must come an increased attentiveness to the means of defending against them. The offensive cannot be given greater consideration than the defensive and expect to hold any balance to the equation of preservation of a country's welfare. If aircraft is to become a principal offensive weapon, we must appreciate that it would likewise be developed by any nation that might become our enemy. The recent aircraft maneuvers have rendered invaluable service in proving the importance of a reliable air force. They should likewise give impetus to a thorough study and establishment of anti-aircraft defenses at points of vantage throughout the country.

The Heaviest Single Unit of Ordnance in the World

Will Be Proof-Fired During

The Third Annual Meeting, Army Ordnance Association
Aberdeen Proving Ground, Friday, October 7, 1921

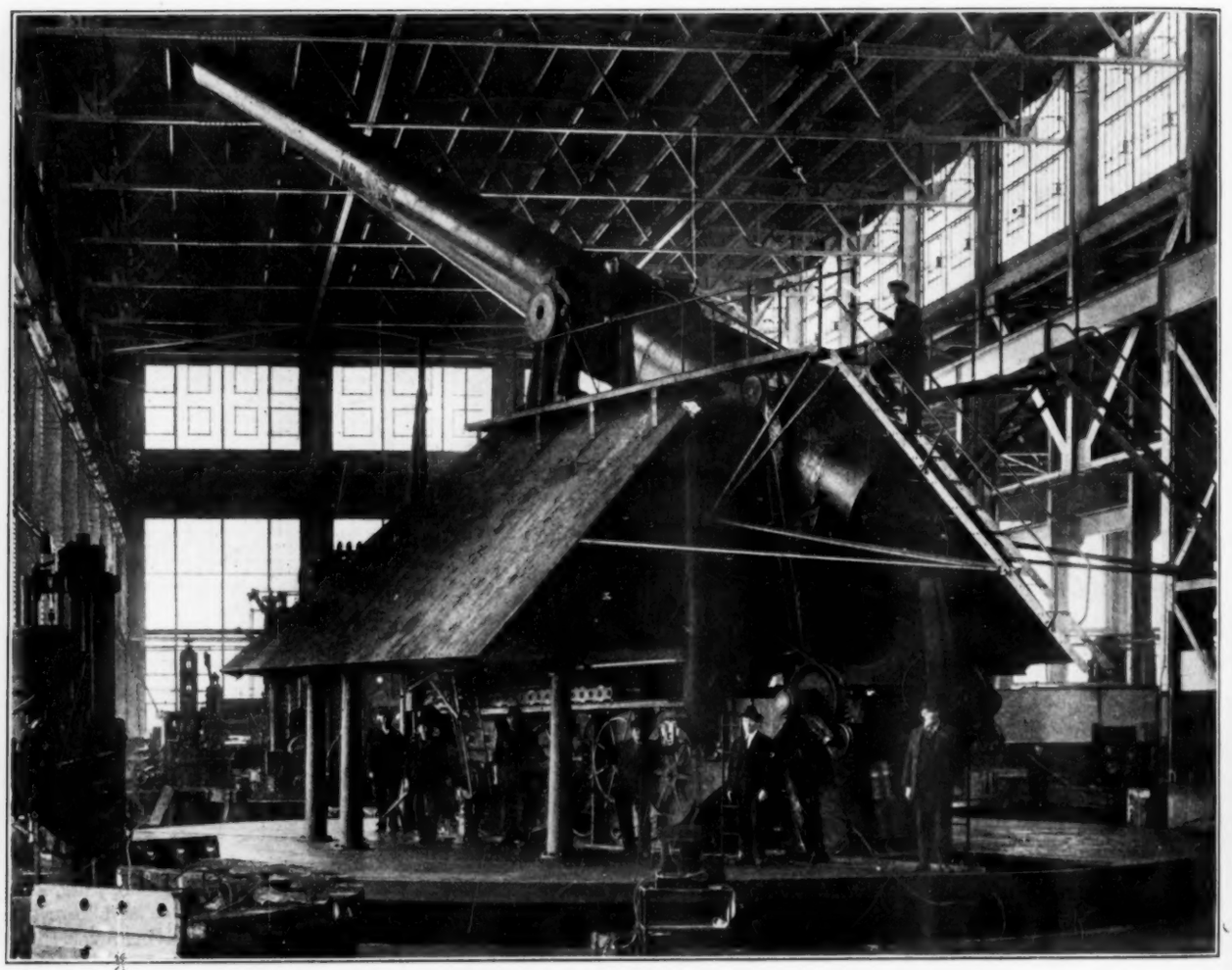


Fig. 1. 16-Inch Gun on Disappearing Carriage in Firing Position—30 degrees elevation

The 16-Inch Gun was designed by the Army Ordnance Department, and built at its arsenal at Watervliet, N. Y. It is about 69 feet over all, weighs 340,000 pounds and requires 850 pounds of smokeless powder to give its 2400-pound projectile its normal muzzle velocity of 2700 feet per second.

The disappearing carriage was designed by the Army Ordnance Department and built at its arsenal at Watertown, Mass. The carriage permits the gun to be fired through 360 degrees of azimuth at elevations up to a maximum of 30 degrees, yielding a range of over 40,000 yards at a rate of one shot per minute. Although the gun and rotating parts of the carriage together weigh nearly 800 tons, they can be easily traversed by one man, and the gun proper can easily be elevated or depressed for range by one man. Although the carriage can be entirely maneuvered by hand, it is also provided with complete electrical equipment for elevating, traversing, lighting and firing. It is about 50 feet from the axis of the gun in firing position to the bottom of the counterweight pit.

Disappearing Carriage for 16-inch Gun

By

G. M. BARNES

Member A. O. A.

A lecture delivered before American Society of Mechanical Engineers, Cosmos Club, Washington, D. C., April 31, 1921, by Maj. G. M. Barnes, United States Army.

I HAVE been asked to give you some of the details of the design and construction of the new 16-inch Disappearing Carriage, for harbor defense. It was suggested that this society would be interested in the construction of this large gun carriage from an engineering standpoint. I will therefore try to avoid any consideration of the carriage as a piece of ordnance and will describe it as a large machine, hoping that some of the problems which have been solved in the development of this large mount may be of interest and possibly may have some direct application to other engineering problems in which you are more directly interested.

This weapon is a 16-inch high-power gun, mounted on a Disappearing Carriage, especially designed for seacoast defense purposes. The gun weighs 170 tons, while the carriage upon which it is mounted weighs an additional 670 tons. When emplaced in the seacoast fortification, the gun and carriage will be in rear of an embankment of sand and concrete of such thickness that the highest power naval guns can not penetrate it.

As this embankment will reach nearly to the height of the gun, when the latter is in the firing position, only the muzzle will be seen from the ocean side. When firing, the shock of discharge, which is equivalent to over eight (8) million pounds acting along the axis of the bore, drives the gun from the firing position into the loading position (Fig. 2), which is approximately 12 feet below the position of the gun as shown in Fig. 1.

The gas pressure acts during the time the projectile is in the bore and for a short time thereafter. The force of explosion of the gun must be absorbed in the carriage so gradually and to such a nicety that there will be no shock or vibration to the carriage parts when the gun moves from one position to another. The gun pointer, who is stationed only 7 feet to the left of the gun, must be able to keep his eye at the telescopic sight during firing and continue to direct the gun upon the target.

Although the gun and carriage weigh approximately 840 tons, they can be easily turned in direction by the power of one man applied at the traversing handwheel. The armor plate shed shown in the illustration protects the carriage and gun crew from small shell fragments, concrete and debris which might fall about the gun if enemy shells should strike the parapet.

Fig. 3 shows diagrammatically the principal parts of the carriage. The gun is attached to the upper end of the gun lever by means of its trunnions. The gun levers are trunnioned near their center to the top carriage, which is constrained to move up an inclined plane 1 degree to the horizontal. The lower end of the gun levers are connected to a cross-head, which is constrained to move vertically in guides.

A very heavy counter-weight (315 tons) is attached to

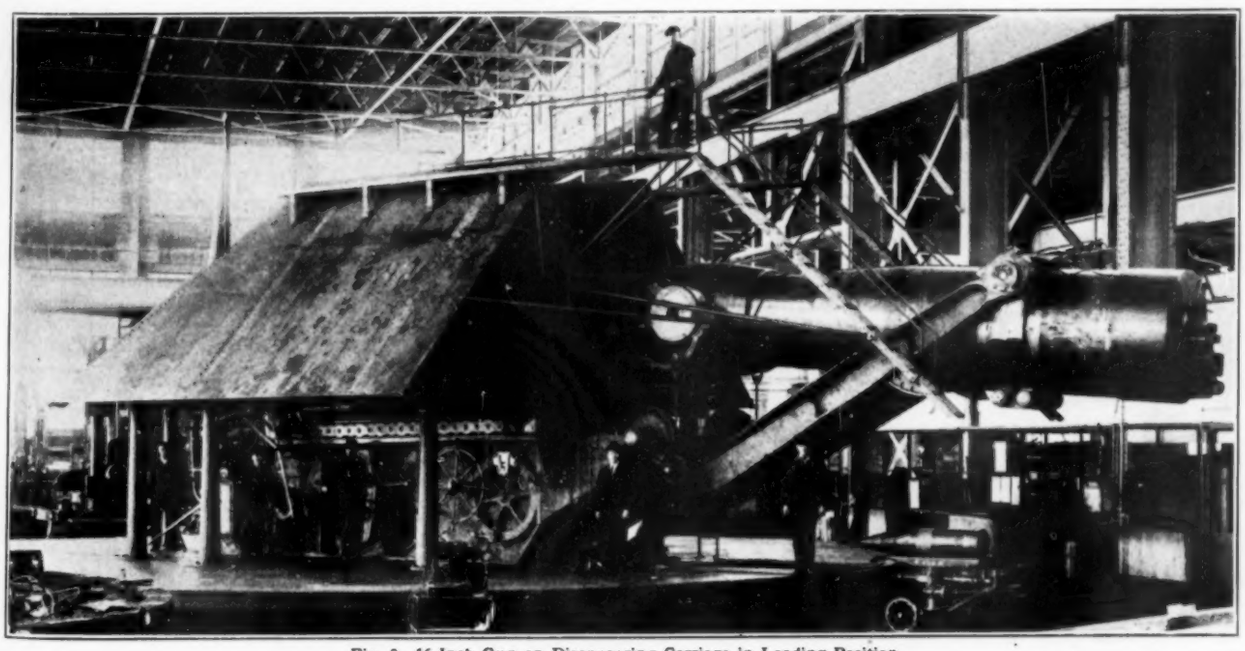


Fig. 2. 16-Inch Gun on Disappearing Carriage in Loading Position

The Carriage lowers the gun 12 feet behind a thick parapet of concrete for loading unobserved by and protected from the enemy. While in this position the elevation at which the gun is to be fired can be set off without interference to loading

the cross-head. The function of this counterweight is to raise the gun from the loading or the recoiled position to the in-battery or firing position. The elevating arm, which is attached to the gun near its breech end, controls the elevation of the piece. The lower end of the elevation arm can be moved up or down. The slide, to which this end of the elevating arm is attached, is constrained by the rear bracket casting to move in the arc of a circle, the center of which is the position of the elevating trunnions in the loading position. The breech of the gun will therefore always return to the same position for loading, regardless of angle of elevation at which the gun is fired.

When the gun is fired the shock of discharge is absorbed mainly in the following ways:

1. In raising the counter-weight;
2. In throttling oil through the varying orifices in the recoil cylinders, which are built into top carriage;
3. In moving the gun, gun lever and top carriage from the in-battery to the recoiled position.

In designing the carriage it is necessary to make a com-

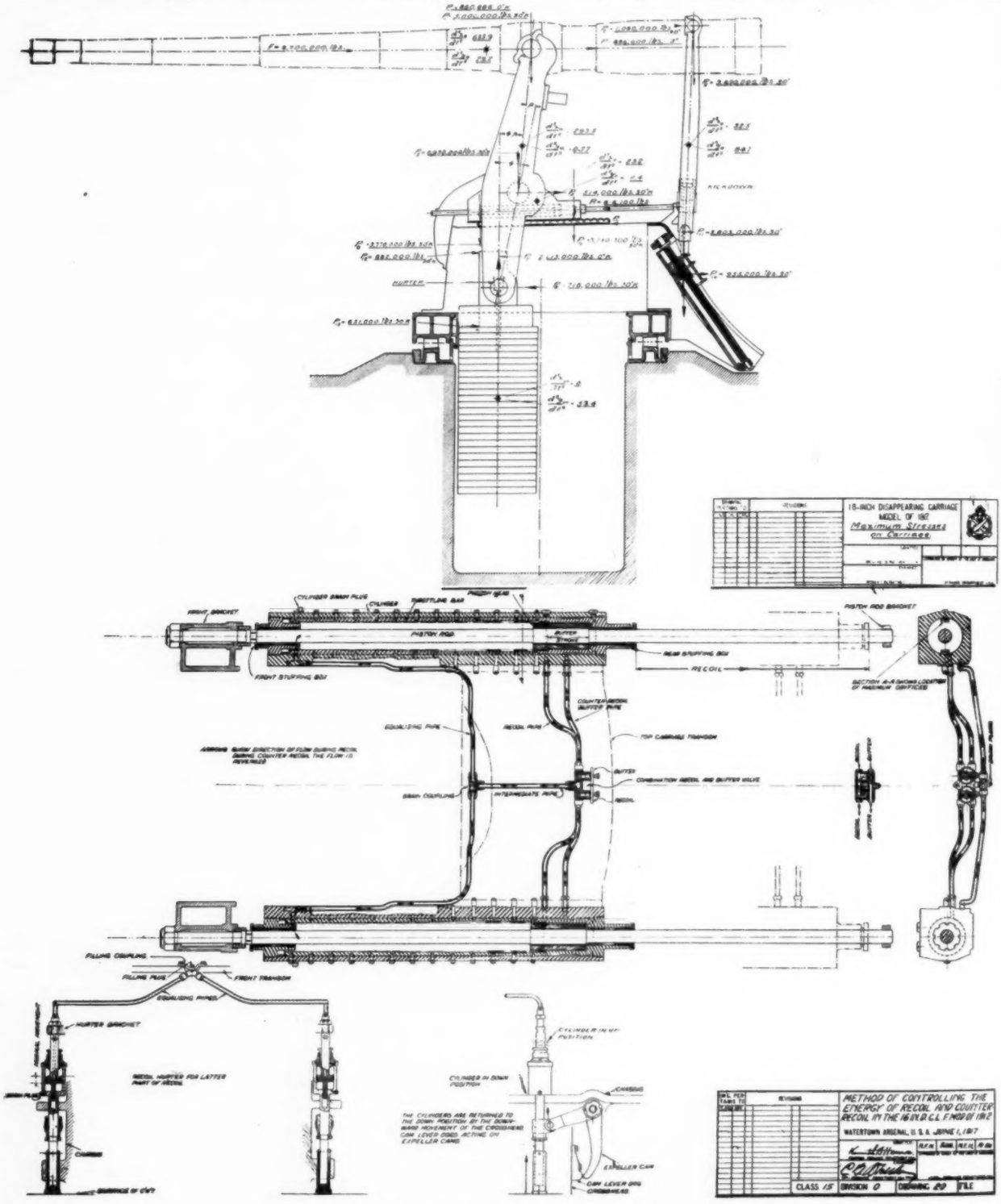

16-INCH DISAPPEARING CARRIAGE
MODEL OF 1917
Maximum Stresses on Carriage
METHOD OF CONTROLLING THE ENERGY OF RECOIL AND COUNTER RECOIL IN THE 16 IN. B.C.L. F MOD OF 1912
WATERTOWN ARSENAL, U. S. A. JUNE 1, 1917
CLASS 15
DIVISION O
DRAWING 20
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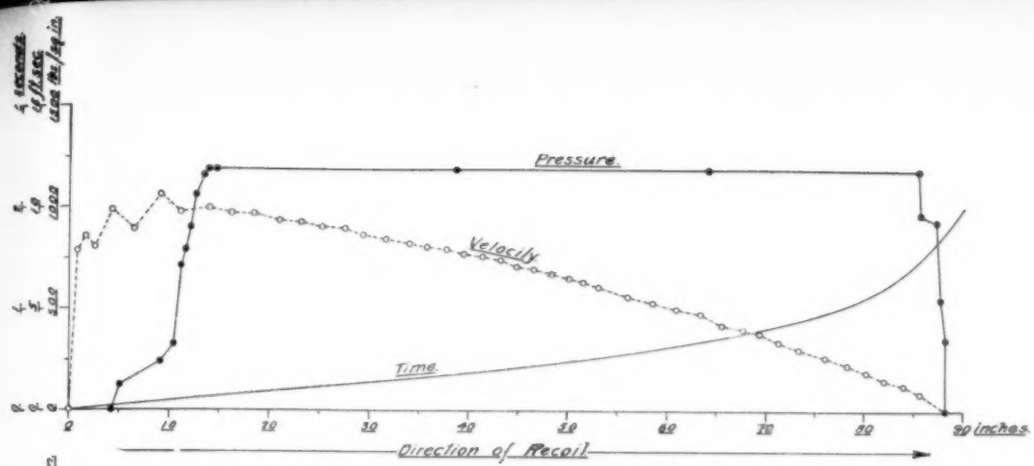
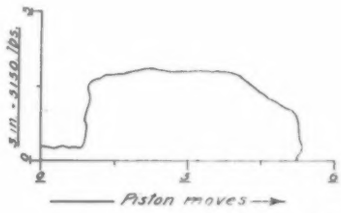
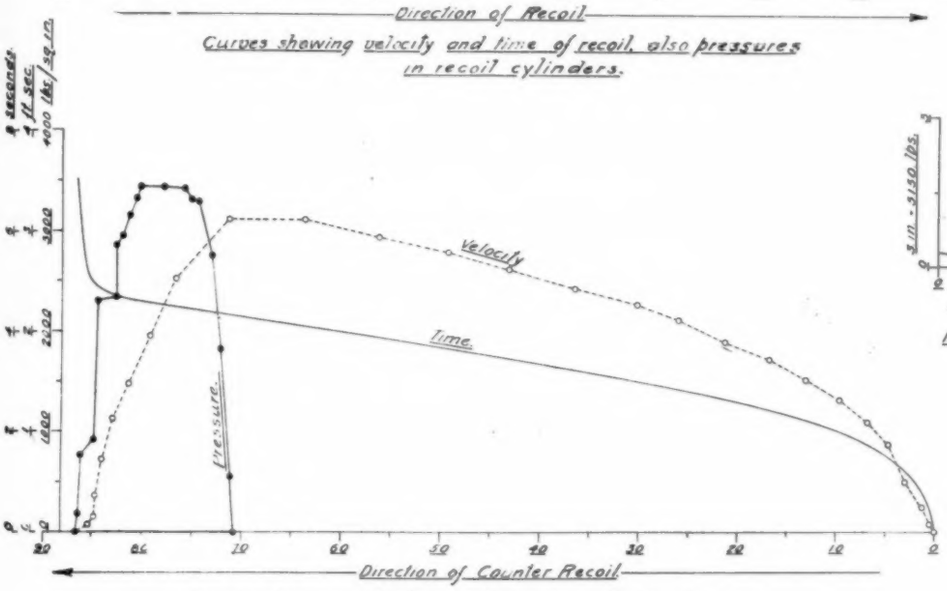
Fig. 3 (above). Maximum Stresses on Carriage
Fig. 4 (below). Method of Controlling Energy of Recoil and Counter-Recoil



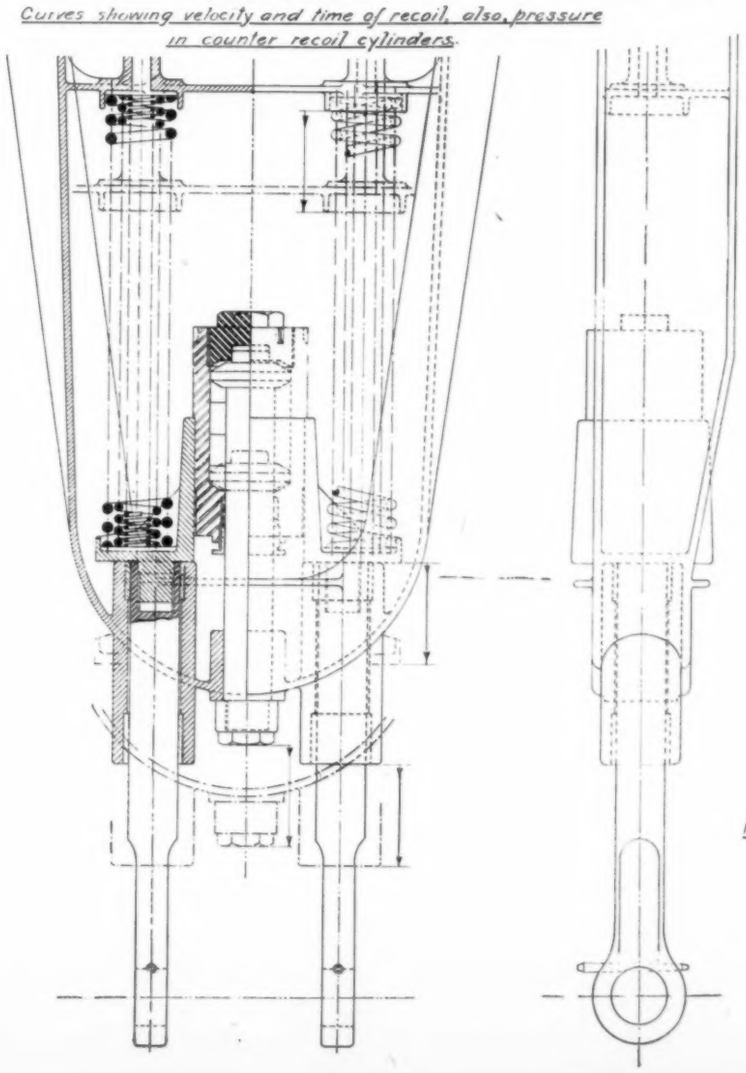
Curves showing velocity and time of recoil, also pressures in recoil cylinders.



Indicator Diagram of Pressure in Hurler Cylinder.



Curves showing velocity and time of recoil, also, pressure in counter recoil cylinders.



ELEVATING ARM
KICKDOWN CYLINDER.

plete solution of the forces acting on the various members and to proportion the parts accordingly. The method used in determining these forces is given in detail in the book "Stresses in Wire Wound Guns and in Gun Carriages," by Col. C. L'H. Ruggles, Ordnance Department, published by John Wiley and Sons, Inc. Anyone interested in the mathematical solution of the forces acting on a carriage of this type will find a solution in this book.

The maximum stresses occur in different members at different angles of elevation. It is therefore necessary to make calculations at various angles of elevation to determine the maximum stress which occurs in each member. Fig. 3 indicates the maximum stresses in the principal members of the 16-inch Disappearing Carriage when the gun is fired. The accelerations of the principal moving parts along the X and Y axis are also given.

It will be noted that the force of the powder gases amounts to 8,700,000 pounds. This force is reduced at the trunnions to $P = 866{,}000$ and $P_1 = 860{,}000$ at 0 degrees elevation. At maximum elevation P_1 however, becomes 5,000,000 and the carriage parts must be designed to withstand this force. It is interesting to note that P_2 exceeds 2,000,000 pounds. The value of the counter-weight in absorbing the energy of fire is therefore apparent. The piston rod pull is 616,000 pounds, and is assumed to be constant throughout the length of recoil.

It will be seen that the forces acting on the upper end of elevating arm P_2 and P_3 are very large. These forces have been computed on the assumption that this arm is rigid. In order to reduce the force on the elevating arm, it has been made elastic; that is, a second recoil mechanism has been introduced. This recoil mechanism allows the arm to shorten when a large stress is brought upon it. As soon as the stress is relieved, the arm returns to its original length. The introduction of the elastic arm slightly increases the stresses in the gun levers and other members, which must be computed on this basis. The arm still fulfills its function of keeping gun at proper elevation.

A part of the energy of fire is absorbed in the recoil mechanism. This mechanism is simple and consists of two cylinders located in the top carriage. The piston heads and pistons are stationary, while the recoil cylinders move back and forth. The cylinders are formed by two forged steel liners slipped into the longitudinal holes in the top carriage. Two bars, called throttling bars, are bolted to the interior of each cylinder. Two corresponding notches are cut in the piston head. The upper surface of throttling bars is a curved surface and so proportioned that pressure in cylinder is constant over length of recoil.

The arrows indicate the direction of the flow of oil during recoil. The piston rod and head remain stationary while the top carriage moves to the rear. The length of recoil can be controlled by means of the throttling valve, which when open allows the oil in the recoil cylinder to pass to the low pressure side without throttling past the throttling bars. When the gun goes from the out of battery to the in-battery position, the top carriage moves forward and the direction of the flow of oil is reversed. Just before the gun reaches the in-battery position the counter recoil buffer acts. As the male buffer which is part of the piston head, enters the rear end of the cylinder, the oil is gradually forced out. The remaining energy in the gun and counter-weight is thus gradually absorbed and the gun comes to rest without shock. This action can also be controlled by means of the buffer valve which when open allows oil to escape to recoil cylinder.

There is also another device used to help absorb the final energy at the end of recoil and counter recoil. This system, called the hurter system is shown below the cylinders (Fig. 4). Just before the counter-weight reaches its upper position it strikes the lower end of the hurter cylinders. The pistons of the hurter cylinders are rigidly attached to the carriage and are stationary, while the cylinders are movable. Oil in the lower part of this cylinder, which is the high pressure side, throttles past the recoil stem, up through its center and out into the low pressure side. Also before the counter-weight reaches its lower position the hurter cylinder is forced down by the expeller cam and the reverse action takes place. The recoil stems are machined to varying diameters so as to give a uniform pressure throughout the stroke. By means of these various hydraulic systems, the enormous weights move from one position to another without the least shock or perceptible vibration.

How closely the pressure in the recoil cylinders can be kept constant, the assumption made in the calculation, is illustrated by indicator card records taken from the 16-inch Disappearing Carriage, model of 1912. The first diagram shows the operation of the recoil system during recoil. For the first 5 inches of recoil there is no pressure on account of the void left in the cylinder to take care of the expansion of the oil. The pressure quickly builds up to a maximum of about 1,200 pounds per square inch and remains constant over the remainder of the length of recoil. The velocity curve shows that the maximum velocity of the top carriage of about 10 feet per second is quickly reached and that this velocity is reduced almost on a straight line over the length of recoil. The time curve shows that the gun moved from the in-battery to the recoiled position in about 2 seconds. The velocity and time curves were obtained by means of velocimeters.

The second diagram shows the operation of the same system, as the gun goes from the loading or recoiled position to the "in-battery" or firing position. There is no appreciable pressure in the recoil cylinder until the buffer mechanism, previously described, comes into play. This buffer acts for the last 16 inches of counter recoil. The pressure quickly builds up to about 3,500 pounds per square inch and the velocity, which has reached over 3.5 feet per second, is quickly reduced to zero. The time for the gun to move into battery is about 7 seconds.

The third diagram shows the pressure in the hurter cylinders at the end of recoil. The orifices are proportional so that the pressures will remain nearly constant throughout the stroke.

The construction of the elevating arm may be of interest because by making this arm elastic the force which it must carry is reduced from about 4,000,000 pounds to less than 1,000,000 pounds. As stated before, the function of the arm is to hold the piece at the proper elevation and to bring the breech of the gun to the proper position for loading. The diagram shows the lower end of the elevating arm and the recoil mechanism which has been introduced into it. When a suddenly applied load is brought upon this gun, the oil in the cylinder is throttled past the piston head through two grooves of varying cross section, cut in the cylinder wall parallel to the longitudinal axis. The cross sectional area of these grooves is such that a constant pressure is maintained in the cylinder throughout the stroke. The piston remains stationary while the cylinder moves. As soon as this heavy load is relieved, the springs force the arm to return to its original length, and the recoil mechanism again acts to prevent the sudden action of the springs.

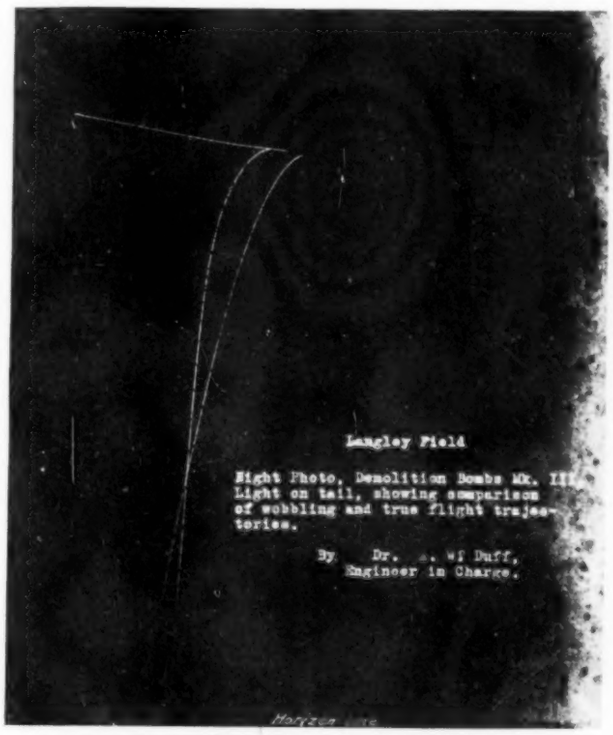
The Study of Bomb Ballistics

By

H. L. DRYDEN

Member A. O. A.

DR. F. C. BROWN, formerly Major, Ordnance Department, and now Assistant Director of the Bureau of Standards, stands sponsor for an interesting anecdote which serves to illustrate the former state of knowledge of most of us concerning the motion of falling bombs. It is said that in the early days of the war a group of officers witnessing some bombing maneuvers at Langley Field were astounded and somewhat disconcerted to see a bomb fall from a plane just overhead. In alarm they scattered in all directions, some even going in the direction of motion of the plane. Our technical knowledge of bomb ballistics has advanced since that time and the purpose of this brief note is to illustrate some of the methods by which advancement has come and is coming, for, although we know more about bombs, we by no means know the whole story.


Langley Field
Sight Photo, Demolition Bombs MK. III
Light on tail, showing comparison
of wobbling and true flight trajec-
tories.
By Dr. ... W. Duff,
Engineer in Charge.

Determination of Bomb Ballistics by Dr. Duff's Method

It will be inferred from the above mentioned anecdote that a bomb dropped from an airplane does not drop vertically, and indeed on reflection it is evident that the bomb initially travelling forward with the speed of the airplane continues to travel forward with that speed in the absence of retarding forces. Unfortunately for the bomb sight designer, retarding forces do act owing to the resistance of the air to the motion of the bomb, but these forces are small so that to a first rough approximation a falling bomb remains vertically beneath the onward moving plane until impact. Neglecting air resistance, the path in space is easily calculated as a parabola and it is possible to devise an instrument with scales on which the height of the plane above the ground, the speed of the plane, and the wind speed may be set off in a manner to give a sighting line such that, if the bomb is dropped when this sighting line of the bomb sight bears on the target, the target is most likely to be hit.

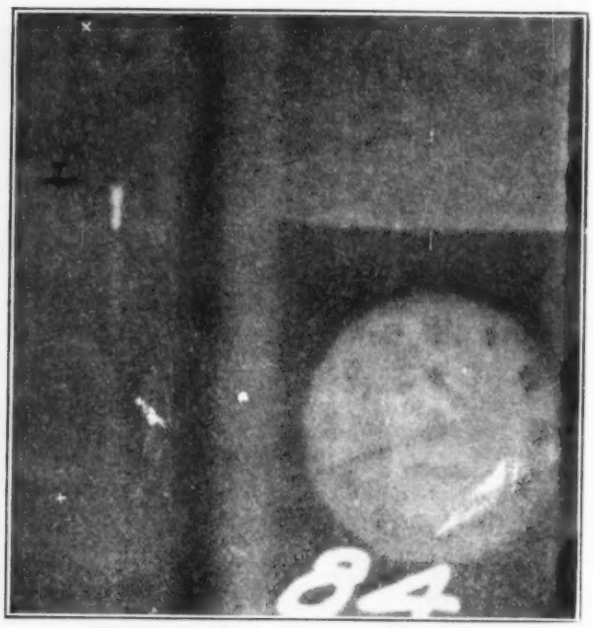
The effect of air resistance is to cause the bomb to lag behind the plane somewhat, the amount of lag depending on the height of the plane, the speed of the plane and the aerodynamical characteristics of the bomb. This lag or trail amounts, in many cases, to several hundred feet and must be known if an accurate bomb sight is to be designed. The first problem in bomb ballistics is to determine the law governing the variation of this lag with the controlling factors of plane speed, height, and the form of the bomb.

It is soon found that when presumably identical bombs are launched under the same conditions as to height and plane speed, different lags are obtained. Some of this dispersion is due to the unavoidable differences of particular bombs from the intended form and to the unavoidable errors in reading the instruments, setting the sight and operating the release. But the dispersion is too great to be entirely accounted for in this manner. It has been found by a method of study described later that the greater part of the dispersion is due to oscillations of the bomb on its trajectory, some types of bombs making complete revolutions about the transverse axis. These oscillations may be reduced by suitable stabilizing fins, but can never be entirely eliminated. Hence a second question arises as to the stability of the bomb, the problem being to construct bombs which fall with minimum oscillation and along a definite trajectory. The general problem of bomb ballistics then is the study of the trajectory of the bomb as determined by the form of the bomb, the speed of the airplane and the height of the airplane, including in the study of the path of the center of gravity the effect of the oscillations of the bomb.

One of the early methods of study and one which is still used with some modifications was to note, by observations from the ground, the point in space from which the bomb was dropped, the point of impact and the time of fall. Without going into the technical details, it may be said that a knowledge of the difference between the actual time of fall and the computed time of fall in vacuo and of the difference between the range and the computed range in vacuo, suitable corrections being made for the wind, is sufficient for bomb sight design. The chief difficulty (which

is inherent in the problem) is in securing sufficient precision of measurement, since these differences are very small compared to the actual time of fall and range.

In a modern form of the method, the plane speed, altitude and point of release of the bomb are determined by



Enlargement of Moving Picture of a Falling Bomb

The bomb and crosses are painted white. The shadow of the plane appears just below the tail of the bomb. In this case the bomb was dropped from a point ahead of and to one side of the camera and is still ahead of the vertical through the camera position although it has trailed behind the vertical through the bomb rack

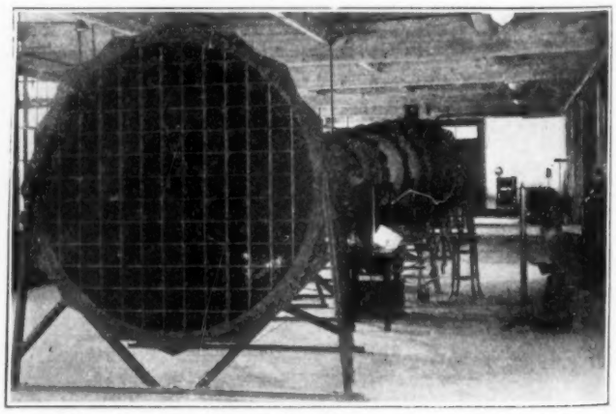
the use of two cameras obscura. (A camera obscura is a large camera inside of which several persons may stand, the "picture" being focused on a piece of paper on a drawing board.) One camera looks vertically upward while the other at the end of a measured base line looks out at an angle toward the first. The plane flies over the vertical camera and releases the bomb just over or a little past it. The operators in the cameras, listening to the tick of a clock, dot in with a pencil the position of the plane on the drawing paper every second for a few seconds before the release and mark the position of the plane at release, which is signaled to them either by a puff of smoke from the plane or by a wireless signal. After the release, the position of the puff of smoke is dotted in for a few seconds. From these records and a knowledge of the constants of the cameras the height of the plane, its speed just prior to release, the wind speed and direction and the location of the point of release in space may be determined. The position of impact is found by the use of two theodolites placed at the end of a measured base line. The time of fall is measured by means of a special chronograph, the signal at release being given by a wireless from the plane and the signal at impact either manually at the sight of the explosion or mechanically by means of a microphone.

It is apparent that, although this method gives information as to the trajectory, if a sufficient number of observations with different plane speeds and from different heights are taken, neither oscillations nor any details of the behavior of the bomb in the air can be studied. In fact, the method is used merely to secure approximate range data and probable dispersion due to all causes. The method is suitable for this purpose, but is not well adapted to the investigation of the causes of the dispersion.

A second method for securing range data for bombs was proposed and worked out by Dr. Duff. A special bomb was used, in the tail of which a source of light was placed. The bomb was dropped at night, and the path of the bomb photographed by two cameras placed at the end of a measured base line and pointing at known angles to the horizontal. The path of the falling bomb is projected on the plates as a streak of light. From the geometry of the cameras and the records on the plate, the range may be computed. The principle is the same as that of the first method, except that the records are in the form of photographs. The method of measuring ground speed and wind speed need not be gone into here. The application is again limited to the securing of range data and the method is not particularly adapted to developmental research.

A third method of studying bomb trajectories is by means of moving pictures taken from the plane from which the bomb is dropped. It is found possible to record practically all the data required on the moving picture film and most of it in a form requiring little computation. In a form of the method developed by Dr. F. C. Brown, a vertical reference line through the plane is determined by the position on the film of the image of the reflection of the plane in a body of water. On the body of water at known distances apart, land marks are anchored, the images of which on the film serve to enable the measurement of ground speed and height. The amount of information which can be devoted to this method is so great that some space will be devoted to the details. The camera is placed on the plane, pointing down and focused for distant objects. On a part of the film there is focused, by means of an auxiliary lens and mirror, the image of a stop watch which may be of the rapid motion type. The camera is located a little to one side of, but on a line with, the center of gravity of the bomb. The film, when developed, shows the reflection of the plane, the land marks, the bomb and the stop watch.

The stop watch gives immediately the time of each exposure. The apparent distance between two land marks, the known focal length of the camera and the known actual distance between the land marks give the altitude of the plane. The variation of the distance from the reflection of the plane to a land mark, together with the time, gives the ground speed. By flying over the course in the opposite direction after the bomb is dropped and re-determining the



Wind tunnel used for obtaining measurements on bomb models
A speed of over 200 foot-seconds may be obtained in this tunnel

ground speed, the wind speed is found. The diameter of the image of the bomb enables a computation of the distance of fall of the bomb. The distance from the image of the plane to the image of the bomb divided by the focal length of the lens is the so-called "angle of trail," which is

the quantity required for bomb-sight design. Thus the primary information is easily obtained from the film.

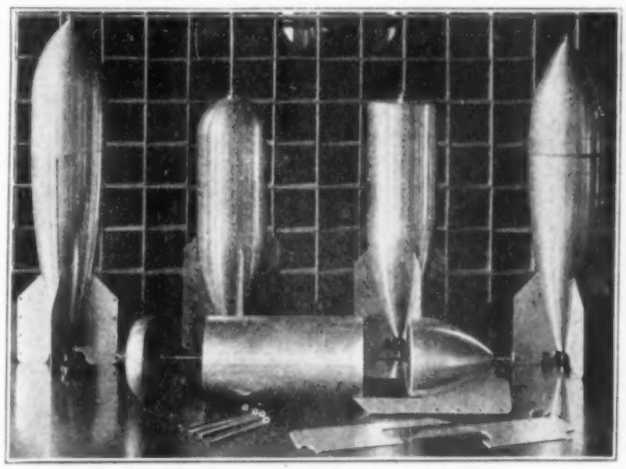
In addition, the length of the bomb image enables the computation of the angular position of the bomb and hence the oscillations of the bomb about a transverse horizontal axis may be investigated. The oscillation about the vertical transverse axis, if any occurs, appears directly as a variation of the angle of the image with the edge of the film. By means of paint stripes on the bomb, motion about a longitudinal axis may be detected. Hence the stability of the flight may be investigated in detail.

Besides this complete information as to the performance of the bomb, it is possible to investigate the behavior of the bombing plane. The distances of the image of the plane reflection from the edges of the film are measures of the inclination of plane about the transverse and longitudinal axes.

This method of study of the problem is the most effective. It has already shown the fact that the oscillations have an important influence on the trail angle and has indicated the importance of the position of the bomb on the bomb rack. Its disadvantage is that reflections occur only under comparatively rare conditions of tide and wind. Other methods of securing a reference line by means of the image of the sun, or otherwise, have been suggested, but none has been satisfactorily worked out. Most of them necessitate the determination of trail as the difference between two quantities very nearly equal.

One other method of study of bomb ballistics may be mentioned here, i. e., by means of wind tunnel measurements. A wind tunnel consists of a large channel through which air may be moved at various speeds by means of a propeller. The air forces on a model of the bomb are measured for various wind speeds and for various angles of the axis of the bomb to the wind. The measurements include drag, cross-wind force and static restoring torque. The laws of variation of these quantities are determined over the range of speeds available and measurements are also made of the damping of oscillations of the bomb.

When the laws of the air force are known, the equations of motion must be solved and the trail angle, range, time of fall, etc., computed. Needless to say, the equations of motion cannot be exactly integrated, but certain methods of computation are available. Much valuable information has already been obtained as to the laws of variation of the air forces, but the results cannot yet be said to be in a form adapted to practical bomb or bombsight design. Ultimately, however, it is expected that it will be possible to predict from wind tunnel tests the complete behavior of any proposed form of bomb.



Models of Bombs Tested in the Wind Tunnel

The nose and tail ogives are made separately from the body so that various combinations may be made up. The model at the right has on it a reproduction of the lugs, welding seams and fin angles found on a full sized bomb. The fin braces shown on the table may be attached

These methods are the chief methods available for studying the properties of bombs. So far we have succeeded in outlining the problem and securing the desired information about certain particular bombs. Finally, it is hoped to be able to go into the drafting room and design a bomb with any desired trail and stability and be certain that the bomb will behave according to prediction. The present method of artistic judgment as to the form of the bomb and the proportion of the fins will be replaced by the only satisfactory method—one based on results of scientific investigation.

From The New York Times, September 14, 1921

CHICAGO, Sept. 13.—A sensational chapter has been added to the "air-craft versus capital ships" discussion that has caused so much comment in Washington this year. This new development comes from a report made by Brig. Gen. William Mitchell, Assistant Chief of Air Service, on the bombing tests held off the Virginia Capes. Gen. Mitchell's report follows:

"Air forces with types of aircraft now in existence or development, acting from shore bases, can find and destroy all classes of seacraft under war conditions with a negligible loss to the aircraft. It is not necessary to destroy hostile seacraft at a distance greater than 25 miles off shore in order to protect the coast, as this distance exceeds the range of most powerful guns installed. Aircraft, acting from suitable floating airdromes, can destroy any class of surface seacraft on the seas.

"Conditions of weather affecting the air and sea conditions do not alter the statement made above, as aircraft can operate in conditions under which seacraft cannot operate. There are no conditions in which seacraft can operate efficiently in which aircraft cannot operate efficiently.

"The weapons used in recent exercises against the seacraft were bombs alone. Torpedoes, gas, gunfire and mines were not employed. The army air service was not permitted to attack the targets, as it would under actual conditions; never was more than one-tenth of the brigade employed in a single attack.

"Had the army air service been permitted to attack as it desired, none of the seacraft attacked would have lasted ten minutes in a serviceable condition. The first provisional air brigade could have put out of action the entire Atlantic Fleet in a single attack. The value of the airplanes in the first brigade did not exceed the cost of a modern destroyer."

General Mitchell then explains how battleships under war conditions are much more vulnerable than the targets used in the bombing tests. A battleship with full steam up and speeding ahead is a target much easier to hit and to put out of commission than the targets used, he asserts.

"The problem of destruction of seacraft by forces has been solved and is finished," the report goes on. "It is now necessary to provide an air organization and a method of defending, not only our coast cities, but our interior cities against the attack of hostile air forces. Our recent manœuvres show an enemy having gained control of the air—which gives him control of the sea—may land air forces from airplane carriers on any of the islands or keys along our coast, which cannot attack by troops or artillery, and from those points launch air attacks against our centers of population, extending to Chicago, St. Louis and other Middle Western cities."

. . . . . .

In conclusion, Gen. Mitchell recommended—

(1) The establishment of an air force for frontier and coast defense. (2) The equipment of the navy for offences on the high sea, and not for coast work. (3) Navy control should cease 200 miles from shore, protection of land and the coast defense being left to the army and the air service. (4) A more co-ordinate and working understanding between the different arms of the service. The present system, a heritage of our early wars, has clearly demonstrated that the present lack of co-operation is a serious fault.

"In this connection," the report states, "an efficient solution of our defensive needs will not exist until a department of national defense is organized with a staff common to all services. Subsecretaries for the Army, the Navy and for the Air Service must be created."

75-mm. Gun Carriages, Models of 1916 and 1920

By

H. C. ZIMMERMAN

Member A. O. A.

THE guns mounted on these carriages differ as follows: The Model 1916 gun has a drop block and is fired by operating the firing handle, which is located on the left side of the cradle; the Model 1920 gun has either a sliding block or a rotating block like the French 75's, and either type is fired by a lanyard. The Model 1916 gun is shorter and of less weight than the Model 1920.

The carriages, Model 1920, meet the specifications of the Westervelt Board, under which they were designed, except for the traverse and weight. The horizontal arc of fire of 360 degrees, as specified, is impracticable on a wheeled mount, and the weight limit of 4,500 pounds for the carriage and limber, with equipment, is exceeded by the difference between the weight of rubber and steel tired wheels. If the vehicles were equipped with the standard 56-inch steel-tired wheel, as used on the Model 1916 (the axle arms are standard for 56-inch wheels), in place of the 48-inch rubber-tired wheels, the weight would be less than 4,500 pounds.

The Model 1916 carriage has a hydro-spring recoil and counter recoil mechanism, the recoil cylinder being above the gun and recoiling with it.

The Model 1920 recoil mechanism is hydro-pneumatic, and both the recoil and counter-recoil devices are contained in a forging on which the gun slides and to which the trunnions are attached. The initial air pressure is 600 pounds per square inch.

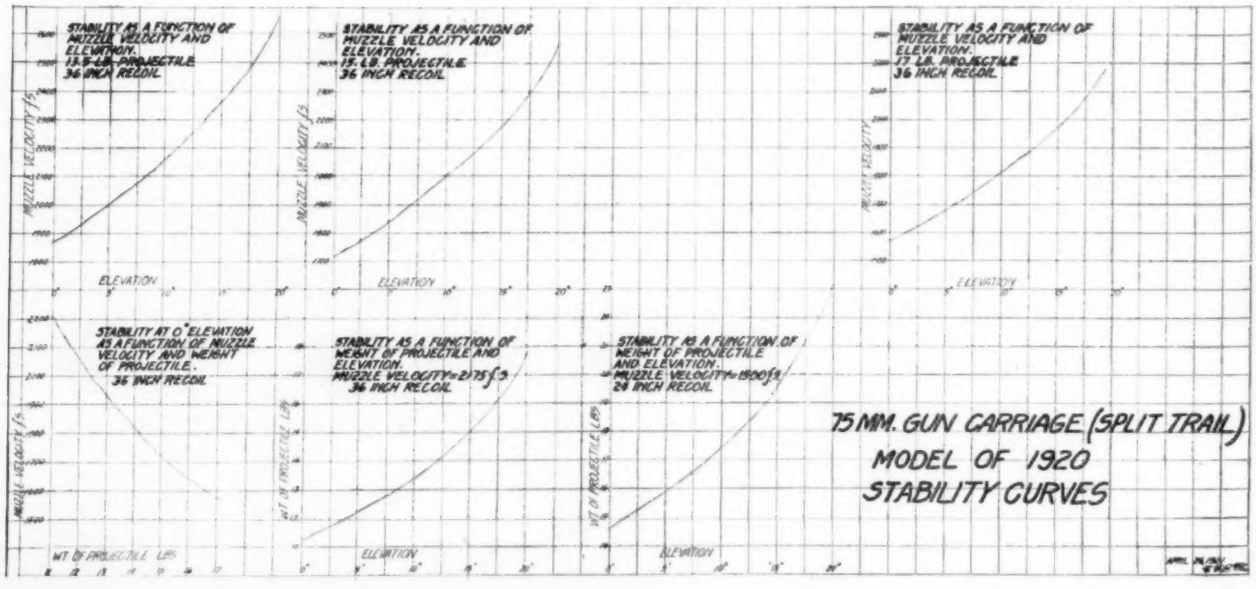
The trunnions are located about 15 inches to the rear of the center of gravity of the tipping parts on the Model 1920. Spring equilibrators, attached to arms on the ends of the cradle trunnion and supported by the equilibrator bracket on the top carriage, balance the tipping parts with the gun in battery. By locating the trunnions near the rear of the cradle and using equilibrators, the ground clearance is increased when the piece is fired at elevation. The equilibrators exert a force on the trunnions that produces friction and therefore increase the load on the hand-wheel when elevating or depressing.

When equilibrators were first considered, it was thought necessary to connect them by a chain operating over a cam to the tipping parts. The cam was designed so that the effective radius when multiplied by the load on the spring gave the proper torque to balance the tipping parts at various elevations. Recent studies have shown that by properly selecting the fulcrums for attaching the spring case, the varying torque at different elevations can be made proportional to the spring load at that elevation and the cam is not required.

The independent line of sight is used on the Model 1916 and Model 1920 carriages. On the former there is a rocker of such a shape that it fits the cradle trunnions and extends under the gun, where a segment of a worm gear is machined on the underside. This is an expensive piece to forge and machine. There are two rockers on the Model 1920 carriage. They are flat plates, except where they fit the cradle trunnion and on the outer edge, on which teeth are machined to engage the elevating pinions. An angle of site hand-wheel is located on each side of the top carriage. By means of these hand-wheels the rockers can be leveled for indirect fire, or the sight, which is located on the left rocker, can be kept on the target for direct fire.

The gears in the elevating, angle of site, and traversing mechanisms on the Model 1920 carriage have been made larger and of simpler design than on the Model 1916.

Due to the high elevation, the top carriage of Model 1920 is radically different from the one on the earlier model. A


STABILITY AS A FUNCTION OF MUZZLE VELOCITY AND ELEVATION. 13.9 LB. PROJECTILE 36 INCH RECOIL
STABILITY AS A FUNCTION OF MUZZLE VELOCITY AND ELEVATION. 15 LB. PROJECTILE 36 INCH RECOIL
STABILITY AS A FUNCTION OF MUZZLE VELOCITY AND ELEVATION. 17 LB. PROJECTILE 36 INCH RECOIL
MUZZLE VELOCITY f/s
ELEVATION
STABILITY AT 0° ELEVATION AS A FUNCTION OF MUZZLE VELOCITY AND WEIGHT OF PROJECTILE. 36 INCH RECOIL
STABILITY AS A FUNCTION OF WEIGHT OF PROJECTILE AND ELEVATION. MUZZLE VELOCITY = 2175 f/s 36 INCH RECOIL
STABILITY AS A FUNCTION OF WEIGHT OF PROJECTILE AND ELEVATION. MUZZLE VELOCITY = 1500 f/s 24 INCH RECOIL
WT OF PROJECTILE LBS
75 MM. GUN CARRIAGE (SPLIT TRAIL) MODEL OF 1920 STABILITY CURVES

steel pin, 6 inches in diameter, secures the top carriage to the center of the axle.

The equalizers on the Model 1916 carriage were segments of bevel gears, so arranged that both trails would take their share of the force during recoil. The Model 1920 carriage has an equalizer consisting of a cross-beam connecting lower end of center pin with equalizer arm that fits around the axle and to which the trails are secured. This arrangement is simpler to manufacture and is easier to keep clean than the other. All moving parts are bushed with bronze.

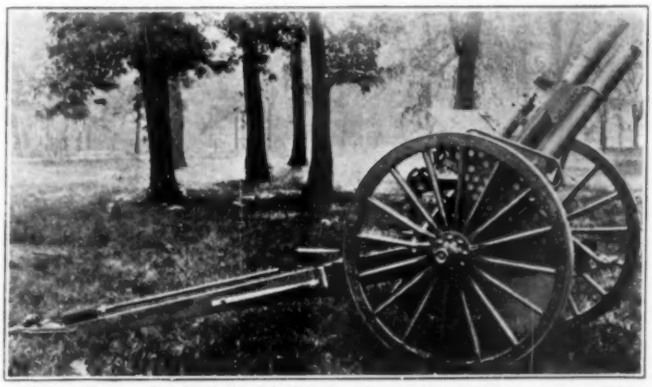
The trails of the Model 1916 carriage are formed of two channel sections that overlap and have a line of rivets on both the top and bottom for the full length. This is a difficult job of riveting. The Model 1920 carriage has the trail formed of a deep channel and a shallow one. These are held together by rivets so located that they can be readily inspected and replaced if necessary.

The shields on the Model 1920 carriage are in two parts—one a fixed shield with apron, which is secured to the axle, and the other the movable shield with its apron, which is secured to the cradle and elevates and traverses with it. The shield was one of the most difficult designing problems on the carriage. The success with which it was accomplished can be appreciated by looking at either a front or rear view of the carriage.

The wheels have the standard hub boxes and rings on both carriages. The Model 1916 uses the standard 56-inch steel-tired wheel, and the Model 1920 has 48-inch wheels with 4-inch rubber tires.

Band brakes with steel drums 14 inches in diameter are used on both models of carriages. The brakes on the Model 1916 are operated by a hand lever in the rear of the shield when firing, and by a foot lever by the man on the axle seat when on the road. This man, facing the rear, could not see the team and was therefore at a disadvantage when operating the brake. The brakes on the Model 1920 should not be set when firing, as the opening or closing of the trails affects the length of the brake line and may damage it. The brake is applied by a man riding the limber by means of a handle and line from the brake lever on the trail. The efficiency of the brake was demonstrated in the road test at Rock Island Arsenal, where it was possible to stall the engine of a 3-ton motor truck drawing a limber and carriage at 15 miles per hour on a macadam roadway by pulling the handle on the end of the brake line with one finger.

One of the Model 1920 carriages was given a 100-mile road test at Rock Island Arsenal. One carriage remains at the arsenal, where further work has been authorized to improve the action of the counter recoil buffer and to improve the efficiency of the gearing by eliminating binding in the shafts and gears. Three of these carriages are at Aberdeen Proving Ground. All the carriages have had preliminary firing at the Arsenal to insure the safety and proper functioning of the guns and recoil mechanisms.



75-mm. Gun on Carriage. Model of 1916. 53 degrees elevation, extreme left traverse

The stability curves are theoretical for 36-inch recoil. The recoil mechanism will be adjusted to 45-inch recoil with an increase of stability.

The general characteristics of these carriages are as follows:

Weights, dimensions and ballistics 75-mm. gun carriages.

	Model of 1916	Model of 1920
Weight of gun and breech mechanism ..... pounds	749	1,242
Length of gun ..... inches	90.9	131.7
Length of gun ..... calibers	28	42
Muzzle velocity ..... ft. per sec	1,693	2,175
Maximum range (shell) ..... yards	12,360	15,100
Maximum elevation ..... degrees	53	80
Maximum depression ..... degrees	7	7.5
Maximum traverse (total) on carriage ..... mils	800	533
Weight of shell ..... pounds	12.2	15
Weight of shrapnel ..... pounds	16	17
Length of recoil ..... inches	46-18	45-18
Weight of gun and carriage .. pounds	4,553	4,800
Diameter of wheels ..... inches	56	48
Width of track ..... inches	60	60
Height of axis of gun above ground ..... inches	41.625	39
Weight at lunette, carriage limbered ..... pounds	140	125
Overall width of trails when open ..... inches	130	90.625
Overall length, muzzle of gun to end of lunette ..... inches	173	183.5
Length, center line of wheels to center of lunette ..... inches	118.28	101.5
Weight of one wheel ..... pounds	192	295

75-mm. Gun on Carriage, Model of 1920

Left: 0 degrees elevation, extreme right traverse. Right: 0 degrees elevation and 0 degrees traverse

Gyro Compass for Tanks

By

ELMER A. SPERRY

COLUMBUS had no trouble with his compass. In fact, it was this first voyage westward that enabled the great discoverer to establish the refinement in compass readings known as "variation," which has been used ever since. But as ships have been built more and more from iron and steel, compasses used to guide them have given more and more trouble, up to the point of almost complete eclipse, from still another source of serious error, known as "deviation."

Years ago this reached its climax with the revolving turret in case of battleships, and recently in submarines, where the compass is surrounded on every side by masses of iron and steel. One reason for this difficulty is that these masses are very much better conductors of the earth's magnetic lines than air—in some instances approaching 2,000 times better—so that these lines indicating the magnetic meridians at any place on the earth's surface, in their northerly journey towards the pole, instantly enter any piece of iron that lies in their path, passing into it with the greatest celerity and emanating at the northernmost end —outward, onward and northward—making their farewell bow in the form of a permanent charge of magnetism or a magnetic pole which they leave behind them in the mass.

What about the compass in this relation? If it is in the vicinity of these large masses of magnetic material, it finds itself embarrassed; it is in an extremely impoverished field because all the lines have been enjoying themselves in a free passage de luxe in the iron masses, right past the magnetic needle, without even giving the compass a glance. Again, this blanking effect is almost complete in a submarine, where the masses of steel lie on every side and also very close to the compass. The after effect, however, introduces a still more aggravating factor because the pole thus induced in the mass sets up a counter-attraction to the needle. The little needle, taught to seek the magnetic pole, is charmed to find one nearby and settles enthusiastically to its work; in fact, it is so delighted with its nice little party that it objects strenuously to changing its mind and pointing to any other pole, especially the earth's pole thousands and thousands of miles distant over many horizons, when it has just had the close association of one with which it had been much happier.

So we remove the compass as far from the steel masses as we can, we construct solid copper houses and elevated supports and towers for it out of brass, and call the compass adjuster aboard the ordinary steamship or freighter—his art is hopeless on some types of naval ships. After working many hours "swinging ship," as it is called, he finally induces the compass, half-heartedly at least, to forsake its first love and to finally sluggishly point North or on the magnetic meridian.

The presence of guns or ordnance still further aggravates the situation, consisting, as they do, of the highest possible grade of steel and tempered so as to become a high order of permanent magnet. The compass may be neutralized for these guns in one position, but when they are swung around every compass is greatly affected. The polarity of guns changes almost every time they are fired, especially on a new heading, which has a still more serious effect on the compass.

Again, on board ship the disposition of cargo consisting of machinery and masses of metal is often found to throw the compass out, and after being carefully readjusted, if the cargo shifts in any way, without warning the compass is again found to deviate seriously.

If all this occurs on board ship, think of the vagaries to which a magnetic compass is subjected within the confines of one of our new units, the fighting tank, where the masses of magnetic material, including the guns, are very close at hand and are constantly shifting their heading and changing their relation to the earth's magnetism under conditions of jar and concussion, which aid in constantly changing the polarity of the masses.

There is one other difficulty the magnetic compass finds itself under in the tank, and that is the large amount of motions and oscillations with which the tank is obsessed. It is well known that the comparatively severe motions of an airplane will so upset a magnetic compass as to cause the card to actually spin. The inaccuracies of a magnetic compass even on an automobile is a case in point. It is not generally known that the compass needle constitutes a horizontal pendulum. This is to neutralize dip and is a base necessity. All accelerations and disturbances lay hold of this out-of-balance factor and cause additional motions which, when they happen to synchronize, will often go so far as to cause the card to turn completely around, often repeating the circuit many times, so all sense of location is lost and the compass is rendered entirely useless.

Just here the gyro compass steps in with its entire independence of anything remotely connected with magnetism, depending, as it does, upon the rotation of the earth, giving sturdy and reliable azimith with many hundred times the directive power of the magnetic compass and pointing always on the geographic meridians, which are used exclusively in navigation. Barring the enormous shock and jar present, nothing can happen to the tank to affect the integrity of the gyro compass in the slightest.

The high directive power gives opportunity to drive repeaters and other instruments that are found to be extremely useful in recording the exact path and enabling the operator to retrace his steps at night or in a fog, thus arriving exactly at the starting point, or charting his route with very great accuracy.

Very serious efforts to solve the problem of utilizing the gyro compass on board both water and air craft, which are subjected to the heaviest known pitch, roll and yaw, have not met with success owing to the ballistic or pendulous qualities which up to recently have always been thought necessarily present to insure the proper meridian-finding qualities. A great deal of work has been done in finding methods to completely eliminate ballistics from the gyro compass and the non-ballistic compass has finally been pro-

duced. It was gradually worked up by more and more severe tests until it operated on our wide angle Scorsby with nothing short of wonderful results. This compass was immediately put on board ships both here and in England, where it has been held under observation long enough to convince us that it is a very practical instrument.

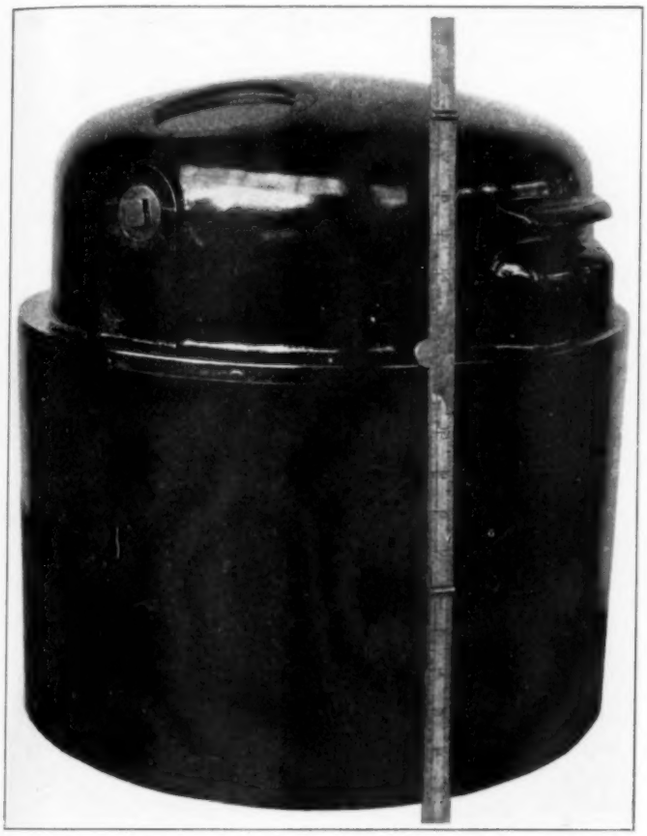


Fig. 1. Gyroscopic Compass for Tanks. In Water-tight, Dust-proof Binnacle

Being totally free from ballistics, the disturbances cannot reach in and get hold of the compass so as to throw it off. Even the enormous accelerations and general disturbances in an airplane, which are probably not duplicated anywhere else except in the fighting tank developed by the Army Ordnance Department, are found to have no effect upon it. The headings and precision of its holding the true meridians have been checked up very accurately by transits during the airplane tests and no amount of turning, banking, accelerations and retardations seem to affect it in the slightest. So it is these experiences which have encouraged us to undertake the still more difficult problem of preparing the gyro compass for the tank, which is described and illustrated herein.

The compass is electrically operated on the battery voltage already present in the tank and has passed the preliminary tests under very rugged, even savage, treatment of the wide angle Scorsby, as stated, and other tests reduplicating the rigorous service conditions.

The gyro compass as adapted to the tank consists of a spinning wheel weighing approximately 25 pounds and rotating at a speed of approximately 7,000 r. p. m. on its axis. This wheel, with its enclosing case, is very accurately supported on the usual horizontal and vertical balancing supports and is suspended from a fine steel torsionless member.

The gyro wheel is driven at this high speed by a specially designed direct current motor, which receives its current supply from two standard 12-volt batteries connected in series. The azimuth motor for orienting the card and actuating the "follow-up" system is a specially designed direct current motor operating from the same source. In the larger class of tanks repeater compasses, recorders and indicators for accurate navigation and fire control are also operated from this master compass.

The complete sensitive element, with its auxiliary parts, is suspended freely and resiliently on gimbals in a solid water-tight and dust-proof bronze binnacle as shown in Fig. 1. Armored cables entering this tank compass through water-tight glands render the compass impervious to the effects of water, dirt, or oil, which, under extreme conditions, may surround it on every side. The sensitive element of the compass has sufficient clearance in the binnacle to allow the tank to roll freely up to angles of 45° and up to pitch angles of 25° without interfering in any way with the precision of its action as a compass.

The glass window in the cover of the binnacle through which the observations of the card and course pointer are made is reduced in size to the limit and is made of non-shatterable glass, so that if accidentally broken the mechanism inside is protected. The top cover of the binnacle is sufficiently heavy to withstand the impact of ejected shell cases, hob-nail boots, and the general rough usage to which material in the cramped quarters of the tank is subjected.

In Fig. 2, where the compass is shown temporarily hung from above, the wheel and inside binnacle gimbals are plainly seen, together with the azimuth motor and azimuth moving support. The rugged character of all of the parts will at once be recognized.

The unique feature on the top of the compass is a set pointer on which the course is set. By this means the pilot at a distance can readily see whether he is making good his course without bothering to read the numerals on the face.

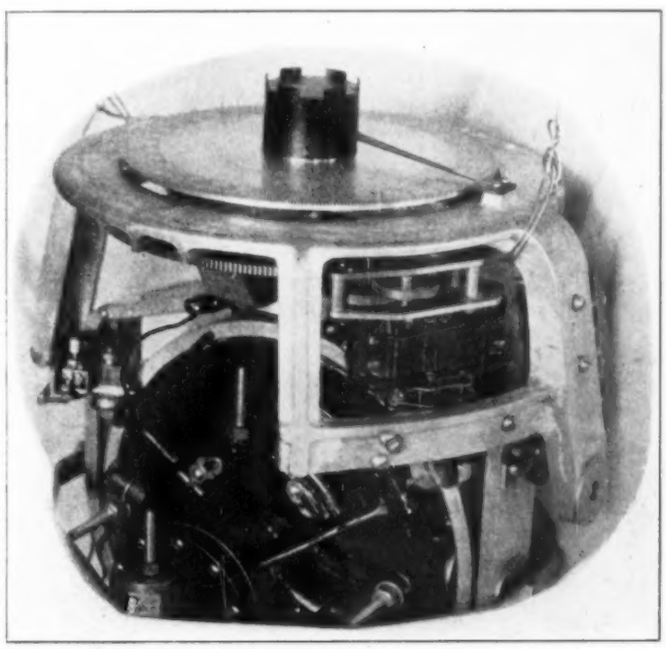


Fig. 2. Interior Mechanism of Gyroscopic Compass for Tanks

Self-Propelled Track-Laying Artillery

By

WILLIAM T. CARPENTER
Member A. O. A.

PART I. DEVELOPMENT OF THE TRACTOR IDEA

[The following article was originally printed in the *Journal of the United States Artillery* for April, 1921, its author, Maj. William T. Carpenter, C. A. C., being awarded First Prize, Essay Competition, 1920. We are enabled to reprint it practically in full through the courtesy of the *Journal*.—ED.]

IN the past, wars have been won by the combined action of all the military forces of the victor and success in modern land engagements has been achieved only after the infantry has gained the vantage point with sufficient power to hold it. To this end all the other arms have been contributory—the artillery, perhaps, holding the first place among them.

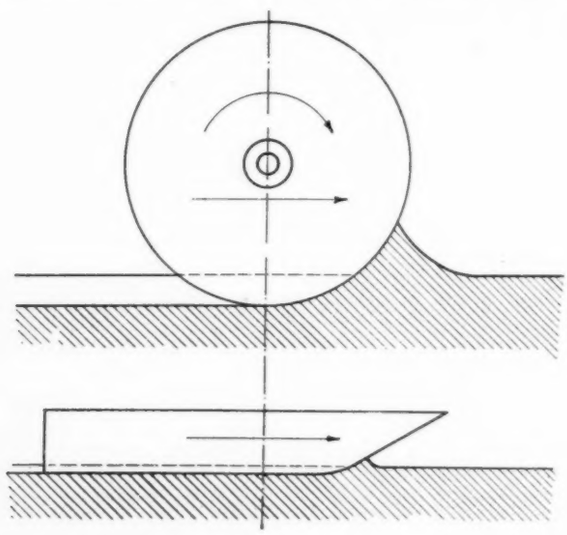


Fig. 1. The Wheel Continuously Climbs a Grade of Approximately 40% When Traveling over Soft Ground, While the Sled Slides Over Soft Ground

As Napoleon said—"Artillery has been and always will be the determining factor of armies and peoples." This statement is as true to-day as it ever was, and in view of the constantly increasing types of weapons and machines of war, the duties of the artillery appear greater than ever before, and most likely they will continue to increase in importance as the mechanical skill of man brings forth newer weapons of warfare. Muscular energy must be replaced by mechanical energy wherever possible, particularly as a prime mover in all the branches of warfare.

Man has always, though sometimes tardily, made use of the peace-time products of his mechanical skill to obtain greater protection, power and mobility in warfare—and as the products of peace-time development have contributed largely to the means of war, so has warfare, in return, contributed much to science and mechanics.

In the past the greatest task of the artillery has been to keep pace with the infantry in open warfare. Artillery must be truly effective to be of aid to the infantry—effectiveness means not only accuracy, equal or superior calibers and ranges as compared to the artillery of the enemy, but mobility as well—mobility to keep up with the advance of the infantry at all times. In this it has not always been successful, and more than once a victorious infantry has been compelled to fall back and relinquish its hard-earned position because the artillery could not follow up in time to enable it to clinch the success of the moment.

During the late war the artillery, with the aid of the gas motor, came nearer the speed of the infantry than ever before—but at times the infantry reached a state of mobilization which in turn again increased the demands for greater mobility of the artillery. In the next war the infantry perhaps will be completely motorized and the light tank, with infantry weapons, will lead the attack. To meet this, every effort must be made to attain the maximum cross-country speed for our artillery of all field types. The cannon must go everywhere that the infantryman goes, hence high speed along railways and well-built highways is not sufficient—the artillery must be able to take the field in every sense of the word. This means that improvements in mobility must not only go hand in hand with those of caliber and range, but in fact the relative gun mobility of the future must go further—it must go far ahead of any relationship it has held with reference to caliber and range.

In the estimation of the writer, the greatest artillery product of the late war was the Self-Propelled Gun Mount of the track-laying type, though it played no active part in the war. It is certain that in the next great war, all other conditions being equal, the victory on land will rest with the side which can first bring into action a preponderance of artillery having the mobility to be obtained only with this type of gun carriage.

Fig. 2. Logging Scene

As in the past, mechanical implements of warfare must depend largely upon the development of their counterparts in commercial life, and the solution of the munitions problem rests largely in the selection and application to military uses of the best developed mechanical principles and appliances of our industries. The advent of this type of gun

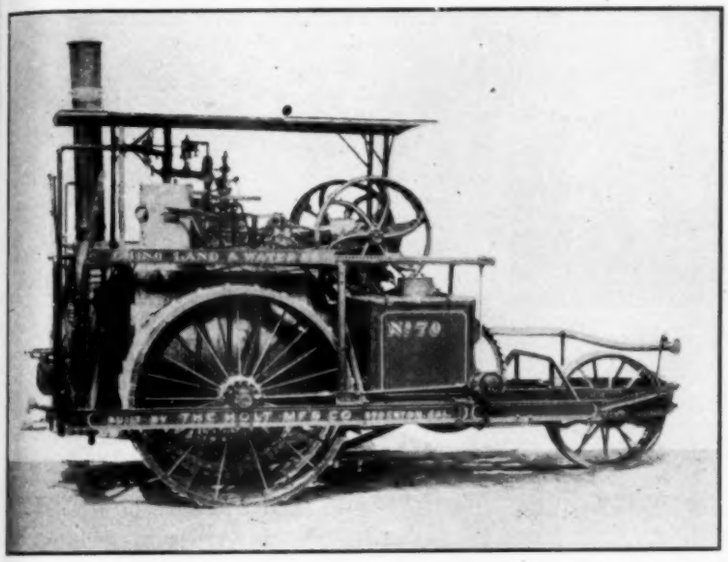


Fig. 3. Late Steam Type Tractor

carriage naturally followed the motorization of heavy artillery by means of the "Caterpillar" Tractor, which long before the war demonstrated its military possibilities by its commercial achievements in all parts of the world.

. . . . . .

The achievements of both the Tank and the "Caterpillar" Tractor, two self-propelled machines of the track-laying type, indicate the possibilities of this basic mechanism as the prime mover for field artillery of all calibers and types. . . .

A story and discussion of the Self-Propelled Gun Mount of the track-laying type would not be complete at this time without reference to the history and development of the "Caterpillar" Tractor.

Development of the Tractor

The invention of the wheel many centuries before the Christian Era marked one of the greatest steps in mechanical science, the first step in our vast system of transportation. In those ancient times it was used not only for domestic power purposes, but for the transportation of building materials as well, and this use of the wheel brought forth the idea of the road or highway, for in utilizing it in transporting those things necessary to his comfort and development, man at once realized that the wheel required a good firm roadway, particularly for transporting heavy loads.

The first wheeled vehicles used for transporting heavy loads were made of round logs and resembled the old-fashioned agricultural roller used in many parts of the world to-day. The logs were of various diameters and lengths, cut to suit the load and the surface conditions of the ground over which it was to be carried. But even these cumbersome wheeled vehicles of large bearing surfaces were insufficient to transport some of the heavier stones used by the ancients in their mammoth structures, and so they resorted to the use of huge sleds, by means of which the resistance of the ground was reduced far below that presented to the wheel when deep in sand or soft earth.

Both human beings and animals were used for draft purposes, and so successful were the Egyptians in their use of the sled that they succeeded in transporting, for considerable distances, stones so huge in size and weight as almost to defy our most modern means of transportation.

The idea of a self-propelled vehicle is also of ancient origin, and various attempts were made to harness men and animals within inclosed war vehicles and to adapt the tread or pedal system to wheeled vehicles—but, of course, muscular power proved inadequate, due to the excessive weight of men and animals as compared to the power developed. The bicycle and other kindred vehicles of modern times are the only practical applications of the idea.

The first great step in mechanical traction was in the use of steam as a motive power for wheeled vehicles. Its effect was far reaching, and the tractive lessons learned at once suggested the necessity for the railroad. The tramway, however, had been in use in England for some time before the advent of the steam engine. Carts drawn by horses along wooden trams or rails were used in many localities, particularly from the collieries to the seaports and other places.

On account of the great expense involved in building the railroad, this type of wheeled traction has, in general, been limited to systems of comparatively straight railway lines of easy gradients connecting the centers of population and natural resources.

Until recent times, animal power was all that was available for draft purposes in the productive fields of agriculture and in those pursuits where it was necessary to haul products and materials in wheeled vehicles to and from the railway lines. This, of course, meant a network of wagon roads as feeders to the railways. The demand for a cross-country engine that would travel and haul heavy loads

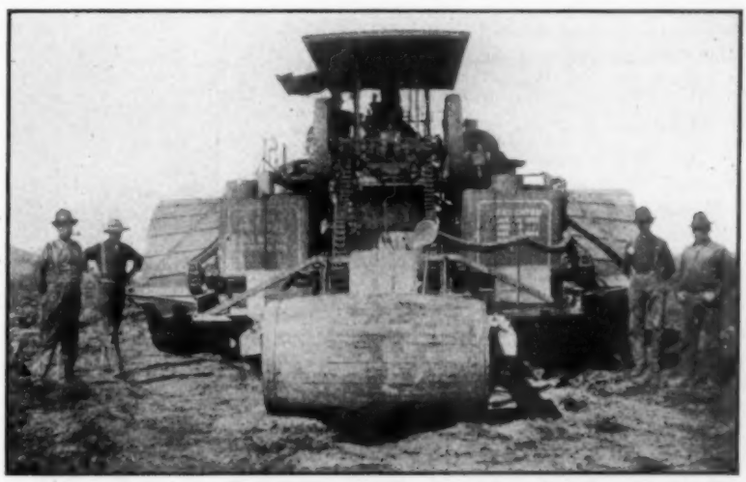


Fig. 4. Tractor with Double Wheels

with its wheels in direct contact with the ground followed immediately after the introduction of the steam locomotive and the railroad. The steam tractor of the wheel type was then developed and greatly improved conditions everywhere, but it could not satisfy the increasing demands for a tractor engine of general application as required particularly in the development of the immense forest and mineral regions where railroads and highways are usually most expensive to build and maintain.

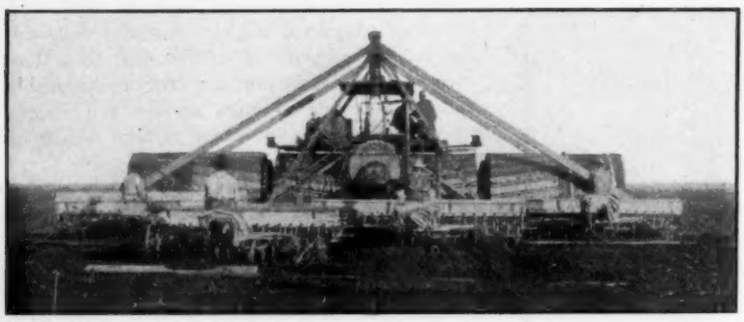


Fig. 5. Tractor with Extension Wheels

The greatest problem in this development was to overcome ground resistance and to obtain sufficient traction or "foot hold" with the historic wheel. It was found that with the wheel comparatively little of the tractive power of the steam engine could be utilized to advantage except upon good, firm, dry ground and fairly level roads. Increases of engine power were obtained at the cost of excessive weight which forced the wheels further into the ground under unfavorable conditions. However, the steam tractor found a useful place and is still used along good roads and on good, firm ground where animal traction was found to be inadequate or uneconomical.

The invention of the gas engine, with its comparatively reduced weight, improved the situation greatly, but it was soon apparent that it would never be possible to build a tractor of the wheel type that would satisfy all the tractive requirements of modern conditions.

Development of the "Caterpillar" Tractor

The idea of the "chain-track," or "track-laying" machine for use as a tractor is an old one, and followed closely after the introduction of the steam engine for use on railways. In 1770, Richard Lovel Edgeworth invented and patented in England a device whereby a portable railway could be attached to a wheeled carriage. This machine passed out to the front, in regular succession, pieces of wood for its use as rails. Following this, various attempts have been made, principally in England and this country, to develop the endless-chain form of track for the same purpose; but it appears that it remained for the late Mr. Benjamin Holt to finally develop and perfect for commercial and military purposes, the modern tractor familiarly known by its trade name as the "Caterpillar" Tractor. This tractor is the product of our great West, where the immense agricultural requirements demanded a powerful machine to replace the great horse teams formerly employed in this work.

In 1883 the late Mr. Holt built at Stockton, Calif., his first steam driven tractor, which was eventually developed into the type shown in Fig. 2. This tractor weighed 44,000 pounds and did the work of 60 horses. It soon became popular on the Pacific Coast, where its use quickly spread from agricultural fields to the various industries of the West, such as lumbering and mining. It was used to haul logs and lumber from the forests and ore from the mines. Its usefulness, however, was restricted to the vicinities of roads and over fairly good, dry, smooth ground.

For 20 years Mr. Holt devoted himself to the manufacture and improvement of this type of tractor, and one of his subsequent models is shown in Fig. 3. This tractor weighed 48,000 pounds and was of 125 horsepower. During this period the improvements consisted of refinements of design with a view to increased horsepower and tractive effort. The size of the wheels was increased in width, as shown in Fig. 4, to meet the various demands. Various wheel systems were experimented with in the constant effort to produce a type that could be used for traction purposes under the most unfavorable conditions, such as those encountered in the rich delta lands along the San Joaquin and Sacramento Rivers of California. A wheel type was finally produced for this work, which permitted of the extension of the wheel system by adopting additional wheels to the driving axle, as shown in Fig. 5. This shows the limits to which the wheel was extended in the contest between the traction engine and nature. This machine, with the two sets of extension wheels attached, measured 45 feet 8 inches in width overall, 36 feet of which was actual wheel width in contact with the ground. The wheels were 90 inches in diameter and the machine weighed approximately

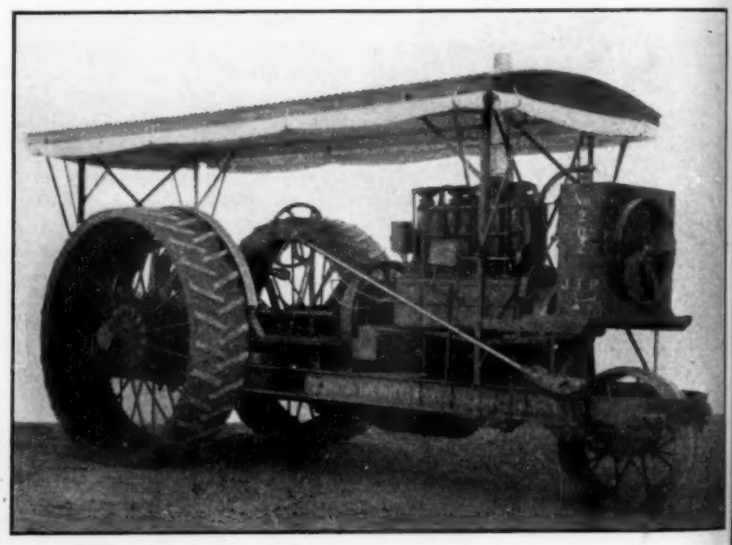


Fig. 6. Gas Motor Wheel Type

(Author's Note: References will be found herein to "Caterpillar" Tractors, Self-Propelled "Caterpillar" Gun Mounts, etc., and also the terms chain-tracks, chain-treads and track-laying will be used with reference to these vehicles. This is done to preserve the distinction between the chain-tread or track-laying type and the particular product of The Holt Manufacturing Company. The general terms properly descriptive of the device popularly referred to since the late war, as "Caterpillar" are chain-tracks, chain-treads or track-laying and the name "Caterpillar" cannot properly be used except to designate a product of The Holt Manufacturing Company, by whom the name is registered as a trade mark.

Where tractors and gun mounts are referred to herein, as "Caterpillar," the reference is to a Holt product directly or a product made otherwise for the United States Government by license agreement; elsewhere the other descriptive terms are used.)

72,000 pounds and did the work of 60 horses.

While this machine did operate successfully over soft marshy ground, it represented little mechanical improvement as the great tractive area gained by the increased horsepower, size and number of wheels was counteracted by the corresponding increase of dead weight and unwieldiness of the tractor, which could not be employed except in immense areas.

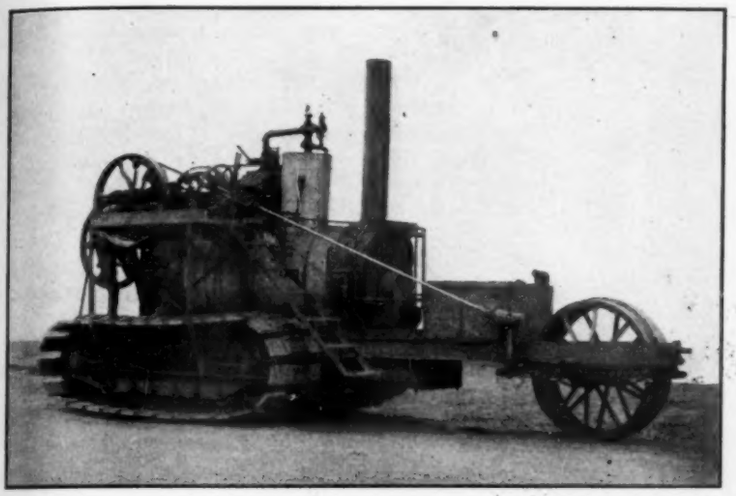


Fig. 7. First Commercial Caterpillar

The multiple cylinder gas engine, which has made the tractor a great commercial possibility, was also experimented with during this period of development, and the tractor shown in Fig. 6 was one of the early applications of the gas engine, in its present form, to the wheeled tractor.

The question of grousers to obtain traction on slippery surfaces, first for the wheel, and later with the track-laying types, has been a serious problem. Various types have been experimented with and produced which give increased traction both with the wheel and track, but as a rule they are so injurious that they are denied the use of public roads; and if made removable much time must be spent in placing and removing them. Much effort has been expended in attempts to produce an automatic cleaning grouser that would not choke up with dirt and lose contact with the ground in sticky soil.

After devoting twenty years to the development of the wheel tractor, Mr. Holt concluded that he and all others similarly engaged were wrong and that a wheel tractor could not be produced which would satisfy all the demands for a traction engine, one which would work over all kinds of ground. The pressure of the wheel packs the soil, which in agricultural work was another serious objection to the wheel type. He then set to work to develop the endless-chain form of track and to adapt it to the wheel. As a result the "Caterpillar" Tractor was produced in its present practicable form. Mr. Holt produced his first experimental "Caterpillar" in 1903, in which the wheels of one of the standard steam tractors were replaced by an endless-chain tread, an adaptation of the old tread-mill idea. The treads were 42 inches wide and the track system, which was slightly curved, had a ground contact length of 9 feet; the equivalent in working contact length of a wheel tractor with driving wheels 75 feet in diameter. A commercial type, Fig. 7, was soon upon the market.

Not long after this the first experimental Caterpillar with a multiple cylinder gas engine was produced. It was one of the first of the track-laying type produced and closely resembles the present Holt "75."

The story of the Holt "Caterpillar" Tractor is only one of the many that might be here recorded to cover the great amount of time and energy that has been devoted to the development of the endless-chain or track-laying type of tractor, not only in this country, but abroad, notably in England. These efforts, of broad application, are now represented by the many different makes of machines utilizing this great mechanical idea, but in this connection the story of the Holt product is particularly interesting, since it was the one predominating type put to military purposes during the late war.

The "Pedrail" Tractor, shown in Fig. 8, was the invention of Mr. B. J. Diplock, of England, who approached the problem from a slightly different angle and who, in 1902, produced his working tractor, which was in reality a combination of animal foot movement with the wheel and rail. This ingenious invention, which was intended to embody the four-wheel drive principle in the final product, was in fact a reversal of the principle of the present track-laying machine, since, with the "Pedrail," the load of the vehicle rests upon short oscillating rails which ride over rollers which are secured to sliding spokes connected to the periphery of the circular frame. The "feet" are secured by ball-and-socket joints to the spokes. This invention goes to show the extent to which efforts were made to solve the traction problem. It is understood that the machine gave encouraging results as compared to the ordinary round wheel tractor; its complexity precluded its commercial success.

The Hornsby Tractor is an interesting type of the chain-track machine which was also developed in England. The illustration shows only the gas motor type. In May, 1908, a 70 H. P. Hornsby Tractor took part in the Royal Review at Aldershot, and during the same year Mr. Hornsby equipped a 75 H. P. Mercedes motor car with a chain-track to

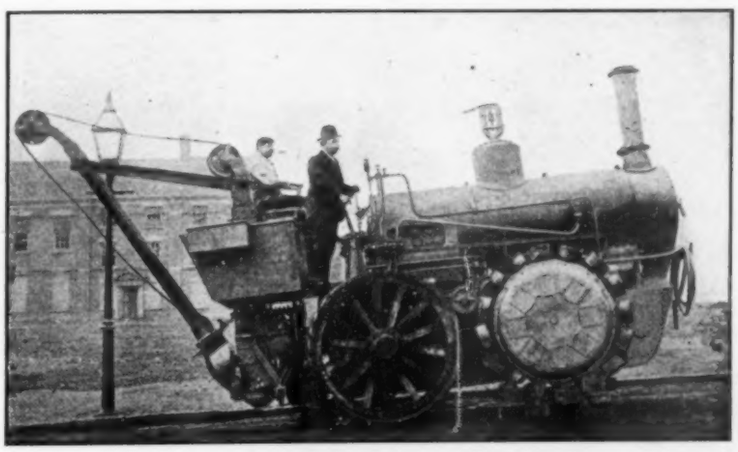


Fig. 8. The Pedrail

demonstrate its advantages for high speed work on sand. "This car was run daily for 5 months at Skegness, on loose sand; it is understood that 25 miles an hour was obtained."*

Description of the "Caterpillar" Tractor

The "Caterpillar" Tractor is a machine of the chain-track or track-laying type, provided with a gas motor power-plant and a power transmission system attached to a rigid frame, supported on either side by trucks with small double-end wheels or rollers, which travel on the rails of the flexible and endless tracks. The tracks are made up of steel links connected by steel pins forming an endless chain. Each link has two rail surfaces, usually about 2½ inches in width, the rail system being the equivalent of four 80-pound railway rails. To the outside of each link is fastened a broad shoe which bears on the ground and therefore corresponds to the cross-tie of the railroad.

Fig. 9. The Hornsby Tractor

The width of the shoe is regulated by the unit ground pressure desired, which should be about 5 pounds per square inch. These shoes are usually provided with holes or slots for attaching grousers when required.

The tracks pass over two sprocket wheels, front and rear, the latter being the driver, the teeth of which engage with the pins connecting the links. The front sprocket or idler, as it is called, has no teeth and serves to keep the track taut.

In the U. S. military types, the motive power is transmitted to the drive sprockets through a master clutch and sliding gear transmission similar to that of the standard motor vehicle, except that the power is finally applied to the driving sprockets by means of clutches instead of through a differential, as with the ordinary vehicle. These clutches, one for each drive sprocket, enable the tracks to be driven simultaneously in the same direction, or either track may be stopped while the other goes ahead, for the purpose of changing the direction of the tractor.

A tractor of this type may be compared to a geared locomotive running on a cogged track, as used by some railroads on very steep grades. The driving sprockets correspond to the driving gears of the locomotive and the links of the chain-track to the cogs of the railroad track. The comparison ends here, however, for the tractor is a cross-country locomotive requiring no expensive railway installation.

It is needless to say that the tractor of the track-laying type has proven its superiority over all forms of wheel tractors for heavy industrial, agricultural and military traction under any and all conditions.

To summarize, the tractor of the track-laying type has demonstrated its superiority in the following activities:

In agricultural fields—plowing, harvesting, cleaning land, ditching and heavy hauling.

In road and canal construction—grading operations, hauling materials and machinery.

In mining—hauling ore, materials and machinery.

In oil fields—hauling machinery and supplies.

In lumber regions—hauling logs and lumber from the forests.

In pioneer land development—heavy freighting under bad road conditions, particularly in the development of roadless regions.

In warfare—hauling heavy guns, ammunition and supplies of all kinds and over all conditions of ground.

The "Caterpillar" Tractor in War

Before the Great War began, the "Caterpillar" Tractor was in commercial use in all parts of the world from Alaska to South Africa. As early as 1912 the Austrian Government became interested in this tractor, ostensibly for agricultural purposes, but as it appeared later on, the adaptation of this tractor to artillery purposes was also of considerable interest.

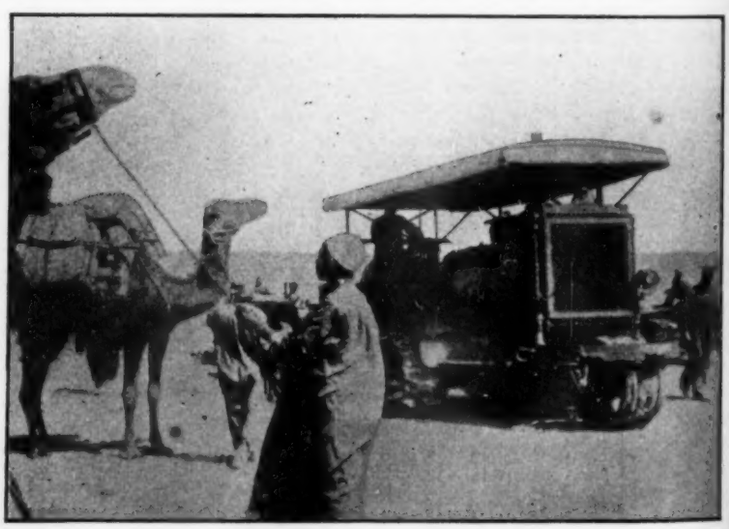


Fig. 10. A "75" in use in Egypt

Fortunately for the Allies, this tractor had at this time reached a state of development and production which at once permitted its adaptation to their military uses, and

*From "Tanks in the Great War," by Fuller.

later enabled them to attain their superiority in mobility of heavy field artillery which played such an important part in the final victory.

The British Government, in the early days of the war, ordered a great number of the 60, 75 and 120 H. P. Holt "Caterpillar" Tractors, principally the 75's. The French

Fig. 11. A "120" Used by the British in Salonika

Government obtained a few hundred of the 45 and a few of the 75 H. P. types, while the Russian Government obtained a few of the 60's and 75's. Under patent licenses obtained from the Holt Company, many more of these tractors were made abroad by the Allies, bringing the total to thousands which were used in many parts of the world.

As a result of experiments started by the Ordnance Department in 1914 and the tests conducted by the Field Artillery Board in 1915, with a commercial "Caterpillar" Tractor, a battery of artillery was motorized in this country in 1916, and during the same year the Ninth Field Artillery, U. S., stationed in the Hawaiian Islands, was also motorized and equipped with a full quota of re-designed 45 H. P. "Caterpillar" Tractors for drawing its guns. It was also during this same year that several of the 75 H. P. "Caterpillar" Tractors were used to supply the Expedition into Mexico, under the command of General Pershing. After our entry into the war in 1917, the Ordnance Department obtained several hundred of the 75 and 120 H. P. types which were afterwards designed as the 15-Ton and 20-Ton Artillery Tractor, respectively. The Department then designed the three distinctly military types known respectively as the 2½-Ton, 5-Ton and 10-Ton Artillery Tractor. The 5 and 10-ton models have given great satisfaction in their respective fields, while the 2½-ton model was produced only in limited quantity and was not utilized to any extent.

Figs. 10 to 12 show various applications of the "Caterpillar" Tractor in drawing artillery during the late war.

The "Caterpillar" Tractor not only revolutionized the transportation and use of heavy field artillery, but the chain-track made possible and gave birth to the Tank, that great mechanical achievement of the Allies over German Kultur which contributed so much to the victory.

The Tank, in turn, crystallized the idea of the Self-Propelled Gun Mount of the track-laying type which was advocated by the builders of the "Caterpillar" Tractor early in the war, but which was developed too late to play an actual part in the war.

(Editor's Note.—Parts II and III will appear in succeeding numbers of ARMY ORDNANCE.)

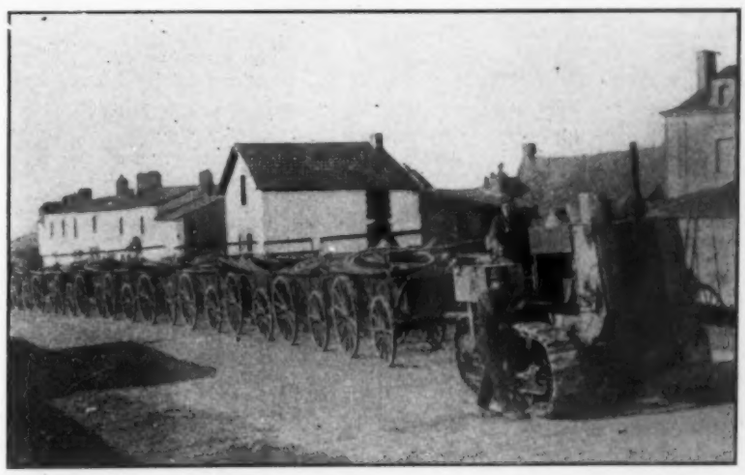


Fig. 12. A 10-Ton Tractor in the A. E. F.

Service Test of Motor Carriages for Army Artillery

A Board of Officers of which Colonel Andrew Hero, Jr., Coast Artillery Corps, is president, is conducting an exhaustive service test under direction of the Chief of Coast Artillery Corps, of a battery of 155 mm. G.P.F. gun motor carriages of the Christie type at Camp Jackson, S. C. Since the issue of this battery of four experimental motor carriages by the Ordnance Department to the 39th Brigade at Camp Jackson about April 1st of this year, these motor carriages have been subjected to extremely severe operating conditions in order to test their reliability as motor vehicles to keep going under such adverse conditions and to determine the ease and accessibility of the carriage for repair in the field under service conditions.

Besides subjecting them to severe operating conditions the Board as its principal objective is seeking to develop the strategic and tactical possibilities of such motor carriages which might form a part of the army artillery. In order to secure data upon which to base conclusions some very interesting tests have been made demonstrating the ability of these carriages in crossing systems of trenches, wire entanglements, shell holes, craters, etc., such as might be encountered in actual service in a battle area.

Long Range Small Arms Firing

PART IV (Continued)

Machine Gun Dispersion

By

GLENN P. WILHELM
Member A. O. A.

BROWNING Machine Gun Dispersion with service ammunition is very dense, with few, if any, wild shots. The beaten zone is long and very narrow at all ranges. When fired from a good barrel service ammunition is so reliable, and the dispersion so constant that at ranges over 1,000 yards on horizontal ground troops can approach to as close as 50 yards of the shortest shot or 250 yards of the center of impact, *providing* the location of the center of impact is known. Shots *rarely, if ever,* fall several hundred yards short of the remainder of the burst, although this is contrary to popular opinion. However, it is necessary to have a large safety angle (distance between attacking troops and target never less than 500 yards); not because the dispersion is large, but because it is impossible to tell where the center of impact, and consequently the dispersion, will be unless the effect of the fire or impact of the bullets can be observed.

When using more than one gun the foregoing remarks of course will not apply.

Comparative Size of Beaten Zones (100, 90, 85, 75 per cent)

Fig. 1 gives comparative sizes of beaten zones for Browning Machine Gun as determined by the A. E. F. in France and the Florida firings with various percentages of shots. Fig. 1A to Fig. 1F, inclusive, on the left of the figure, show at range intervals of 500 meters the size of the 85 per cent beaten zone from 500 meters to 3,000 meters inclusive, the upper zone in each case being the Florida, or Small Arms Ballistic Station (S. A. B. Sta.) firings, and the lower or second zone being the A. E. F. However, No. 1A gives the Florida figure only. It must be borne in mind that the firings from which Fig. 1 was constructed consisted of bursts of about 200 rounds for the Small Arms Ballistic Station firings, and approximately five times this number of shots, or 1,000 rounds (20 bursts of 50 rounds each) for the A. E. F. The right side of the figure shows the comparative sizes of the 100 per cent, 90 per cent and 75 per cent beaten zones as obtained by the A. E. F.

Some variation will be noted in the size of these zones from those previously shown. It will be noted that at least in one case (85 per cent zone at range of 1,000 meters) the 200-round burst of the Florida firings exceeded in size the 1,000-round zone of the A. E. F. This discrepancy simply illustrates the variation that is often obtained in the size of the beaten zone which is not the constant size that it is often taken to be.

Von Merkatz states that "the machine gun sheaf has constant dimensions even under service conditions. The gun pointer is only able to displace the sheaf but not to enlarge it." This is not exactly true. However, he was referring to the fact that the stream of bullets from the gun at one moment occupied approximately an equal space at any other moment during the firing of the burst, similar to a stream of water issuing from the nozzle of a hose, which can be displaced in any given direction without altering the shape or size of the stream.

Variation in Size of Beaten Zone. The exact length of the horizontal dispersion of a machine gun burst is almost entirely an academic question, for there is a greater variation in the length of dispersion of individual bursts at a given range than there is between the length of the dispersion of various bursts at ranges differing by 100 or 200 yards.

Classes of Machine Gun Fire

In order to get a clear conception of machine gun dispersion it is necessary to go into some detail regarding the classifications of fire with reference to the method of delivery. The principle classes of fire as taught at The Infantry School are as follows:

Fixed Fire is fire directed at a single aiming point. The beaten zone is not artificially increased either in width or depth. It is employed on small targets which will be included in the sheaf, to cover a limited area or to secure observation of fire.

Searching Fire is fire directed at a number of points in the direction of depth. It is obtained by successive changes of elevation of the gun. It is employed on deep targets or areas.

Traversing Fire is fire directed at a number of points in the direction of width. It is used to engage wide targets.

Swinging Traverse is continuous traversing fire. It is used at close range to repel an assault or prepare one, and delivered with a relatively loose traversing screw.

Combined Sights is the fire of two or more guns with differences of elevation and a single aiming point. It is used to engage deep targets or to ensure hitting a target whose exact range is unknown. Guns may be laid with combined sights and fix, search, or traverse. It permits the surprise effect which might be lost by ranging.

Machine gun fire is also classified with regard to direction. However, only two classes of direction fire will be considered in this article. These classes are "Enfilade," meaning when the long axis of the target is included in the machine gun beaten zone, as when firing down a narrow way such as a road, etc.; and "Frontal," which is fire delivered at the front of a target or perpendicular to our own front. On account of the character of machine gun dispersion (very long and very narrow, see Fig. No. 1), enfilade fire is naturally the most effective and should be the normal method of applying the fire effect of machine guns. It is practically impossible for troops to advance, regardless of the tactical formation which they may adopt, when

opposed by machine guns so placed that the long axes of the machine gun beaten zones are parallel to, or coincide with, the longer axis of the target. For instance, troops cannot advance on a road in column or cross a road in line when machine guns are located so as to have the road covered with the longer axes of their beaten zones.

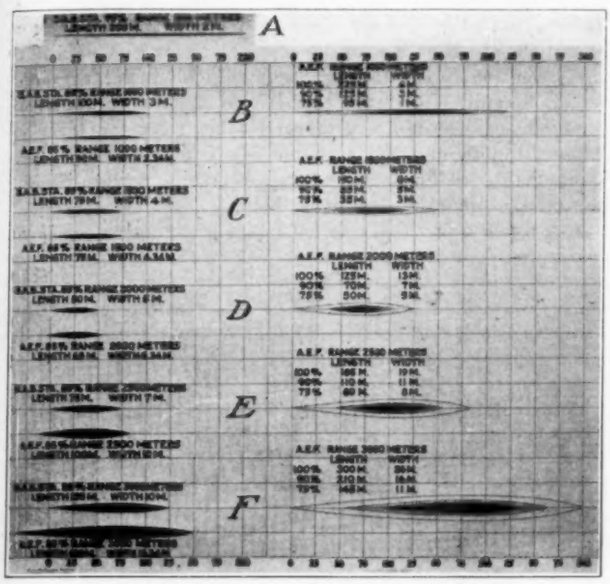


Fig. 1. Comparative Size of Machine Gun Beaten Zone
100, 90, 85, 75 Per Cent

On the other hand, frontal fire, contrary to popular opinion, is more or less ineffective, due to the fact that the longer axis of the beaten zone is perpendicular to the longer axis of the target, so that the intersection of the target and the beaten zone are of the smallest possible dimensions. A machine gun cannot effectively cover a road or narrow target, such as a line of men, by firing perpendicular to such a target, except at the very shortest ranges and against targets of the greatest vulnerability. In such cases traversing fire or swinging traverse may achieve good results.

Fallacy of Combined Sights. Theoretically the use of combined sights with two or more Browning Machine Guns will increase the length of the beaten zone sufficiently to always include any target. Practically, combined sights may not achieve this result as well as fixed fire, as will be shown. However, this is not a plea to do away with combined sights, which, whatever its shortcomings, is the only way of taking care of the probable error in range, except by searching and ranging fire.

Assuming that the exact range to the target is known and taking for example four Browning Machine Guns to be used against a target at a range of 1,700 meters, what class of fire is best adapted to insure that the target will be included in the beaten zone? At first thought it would seem that, knowing the range, by using fixed fire all four cones could simultaneously be laid on the target thus having a beaten zone of the maximum density; and that under any circumstances the use of combined sights would absolutely cover the target.

However, as has already been shown, two factors govern the possibility of locating the center of impact of a burst at a given point even when the range is known, these factors being the unknown line of departure of the bullets for a given elinometer elevation and the effect of weather conditions. The effect of weather can be eliminated as it would affect all four guns the same and the center of impact of each burst would either be short or over, depending on this effect. Also the dispersion of each gun can be considered to be constant.

Fixed fire will first be discussed. Assume each gun has the normal elinometer elevation for 1,700 meters of 57 mils, and that the weather conditions are normal. Assume also that for these four particular guns the difference between the elevation obtained with the elinometer and the actual line of departure of the bullet is as follows:

First gun, plus 2 mils,
Second gun, plus 5 mils,
Third gun, minus 4 mils,
Fourth gun, minus 3 mils.

The average difference of the four guns will then be zero, and these four guns are as representative of the average Browning as any four will probably be.

Then the actual angle which the bullets from the four guns will leave will be:

First gun, 59 mils,
Second gun, 62 mils,
Third gun, 53 mils,
Fourth gun, 54 mils.

Therefore, the center of impact for each gun will be at the following ranges:

First gun, 1,720 meters,
Second gun, 1,755 meters,
Third gun, 1,650 meters,
Fourth gun, 1,660 meters.

The target will then be well within the beaten zone, as what actually resulted with fixed fire has been the same as combined sights are intended to produce.

The actual effect of combined sights will next be considered. Assume all of the guns and conditions to be the same as for fixed fire, and that it has been decided to use combined sights with a difference in elevation for each gun of 50 meters. This corresponds at a range of 1,700 meters to an elevation change of about 5 mils. Therefore the first gun is given a elinometer elevation 7 mils greater than normal; the second gun 2 mils greater; the third gun 3 mils

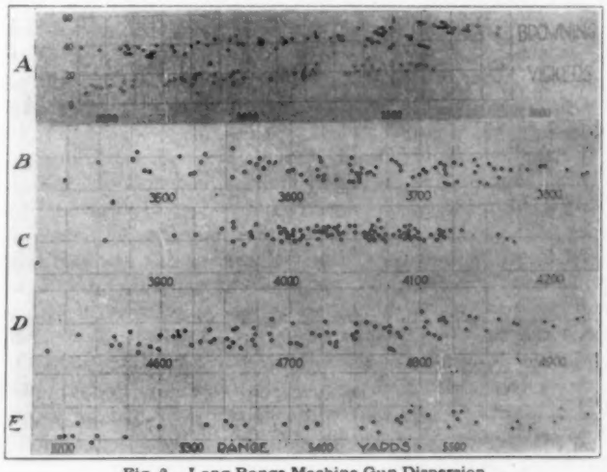


Fig. 2. Long Range Machine Gun Dispersion
No. 2A. Comparison Between Browning and Vickers Machine Guns at Extreme Range
No. 2B. French Hotchkiss 8 Millimeter
No. 2C, No. 2D, No. 2E. Browning with Boat-Tail Bullets

less, and the fourth gun 8 mils less. Consequently the actual elevations of the line of bullets will be as follows:

First gun, 66 mils,
Second gun, 64 mils,
Third gun, 50 mils,
Fourth gun, 46 mils.

Therefore the center of impact of each gun will be at the following ranges:

First gun, 1,800 meters,
Second gun, 1,780 meters,
Third gun, 1,610 meters,
Fourth gun, 1,550 meters.

The target will therefore be entirely missed, as there will be no fire of any kind at 1,700 meters.

This problem, of course, is improbable, although not at all impossible or exaggerated in the slightest. The answer is: Know your guns. Check up the clinometer elevation with the actual line of departure of the bullets by the use of paper screens on the 1,000-inch range. If your clinometer elevation represents truly the actual line of departure of the bullets, one of the most important errors in the application of the fire power of machine guns will be eliminated.

Fallacy of Weather Corrections. There is a tendency, on the part of the machine gunners, of over refinement in making elevation and deflection corrections for weather conditions. Experimental firings in the past have shown that even under the most ideal conditions and with scientific meteorological instruments, it is impossible to precisely determine where a given elevation and deflection will locate a machine-gun burst, eliminating all errors in laying the gun.

Changes in weather, which usually occur during firing of some minutes duration, on the other hand, do not have as great an effect as might perhaps be expected. In other words, while it is hard to determine in advance the location of a machine-gun burst, yet once located it is always somewhere near the original center of impact.

Because of lack of knowledge of the wind conditions, except superficial knowledge of surface winds, which affect the flight of bullets, the machine gunner will find it inadvisable to make corrections for wind velocity for less quantities than 10 miles per hour. Tables should only show winds of 10, 20 and 30 miles per hour. No interpolations should be used, as they are misleading.

Likewise, the direction of the wind should only be classified as right and left winds, and head and rear winds. All winds from 8, 9 and 10 o'clock should be considered to be left winds, while those of 2, 3 and 4 o'clock should be called right winds.

Winds from 5, 6 and 7 o'clock should be assumed to be rear winds, and correspondingly those of 11, 12 and 1 o'clock would be head winds.

Corrections should never be made for both elevation and deflection, as one or the other is almost certain to be wrong. This is contrary to theory, but not to actual practice. A wind which may be blowing 15 miles per hour at 7 o'clock as determined by observation or instruments at the firing point may be a 10 or 20 mile per hour wind at 5 o'clock as determined by its actual effect on the bullets. With such a wind the elevation should be decreased sufficiently to correct for a 10 or 20 mile per hour *rear wind,* the approximate rate to consider the velocity of the wind depending upon the judgment of the fire-control officer.

No correction in elevation should be attempted for local variations in temperature, barometer or humidity.

Large Errors Affecting Probability of Hitting with Machine Guns. The machine gunner will do all and more than can be expected of him if he is able to eliminate the majority of the large errors which affect the probability of hitting the target without bothering with theoretical refinements. These large errors are:

(*a*) Errors in determination of ranges;
(*b*) Errors resulting from the difference between clinometer elevation and actual line of departure due to effects of jump, clinometer and clinometer seat;
(*c*) Unknown effect of wind.

False Conceptions of Machine Gun Fire

Many machine gunners have noticed that when a machine gun is fired with single shots, followed by the machine gun firing automatically, the center of impact of the burst is quite often at a greater range than that reached by the single shots. Now Tartaglia, one of the first claimants to the invention of the original gunner's quadrant or clinometer, maintained in 1528 that if two shots were fired consecutively the second will travel farther than the first, because "it doth find the ayre not onely wholy stirred with the pellet of the first shoote, but also much tending or going toward the place at which it is shot."

Reasoning along this line, officers who should have known better have proposed a similar theory to account for the greater range of the machine-gun burst.

However, their theory does not take into consideration that sometimes the center of impact of the burst is at the same range, or even at a less range, than that obtained by single shots.

The real reason that the machine-gun burst ranges farther than the single shots is because the bullets leave at a higher angle of departure, due to the automatic firing which sometimes tends to raise the muzzle of the gun, and consequently makes the shots range farther, although the clinometer elevation of the gun, which is measured before firing, is the same in both cases. The difference in the range between single shots and automatic bursts is also caused by the bullets leaving at a different period in the up and down vibratory movement of the barrel and gun on its mount, so that the range may even be decreased on account of the angle of departure being less, which is the case when the bullets leave the muzzle with the barrel in its lowest position.

Another misapprehension is the effect of differences in the velocity of bullets on range. An attempt has previously been made to determine the correct sight setting for individual machine guns by firing a small number of test shots, it having been noted that the sight setting for a given range for individual machine guns always varies. From the elevations required on the test shots, by means of a rather complicated table, the correct elevation for the gun to use at all ranges was determined, it being assumed that the differences in elevation required by the individual guns were almost entirely a question of differences in muzzle velocity.

Likewise, it has been popularly understood throughout the Army, on account of the firings which were performed on the beach in France by the A. E. F., that the Vickers Machine would consistently outrange the Browning, both using Service Ammunition, because the four inches longer barrel of the Vickers gives a greater muzzle velocity.

The experiments upon which this idea was based were faulty, in that both guns were not fired simultaneously. Simultaneous firings with both the Browning and Vickers with equal elevations have shown no appreciable difference in extreme range, and with differences so slight at mid range as to be negligible, as these differences were less than the variations which is obtained with one type of gun using the same ammunition but fired at different times. Fig. No. 2A shows the machine gun beaten zone at extreme range for service ammunition for both the Browning and Vickers machine guns. From this figure it is evident that there is no difference in ranging ability of the two guns. Incidentally the same is true, with regard to extreme range, of the Springfield Rifle (Model 1903) and the American Enfield

(Model 1917), although the latter has a barrel four inches longer than the former.

Of course, differences in velocity do make a difference in range, so that the higher the velocity the greater the range, providing the bullet still has gyrostatic stability. However, as the muzzle velocity increases it is also true that the bullet also loses velocity faster.

Experiments were also conducted with Browning Machine Guns having various lengths of barrels, and the difference in ranging ability of individual guns with standard barrels has clearly been shown to be due not so much to difference in velocity, but to the difference in the actual line of departure of the bullets, although the clinometer elevations may be equal.

This is a serious defect of recoil-operated machine guns, which, on account of having a moving or floating barrel, not only results in a considerable increase in the size of the shot group or dispersion, but also results in variations from time to time between the actual line of departure of the bullet and the rear sight leaf or clinometer elevation. It is remarkable that with the exception of the French Hotchkiss Machine Gun, the majority of the other successful machine guns, including the German Maxim, the Englsh Vickers and the American Browning, are all recoil operated. This has been brought about by the superiority of the recoil-operated machine guns from a mechanical and manufacturing standpoint over the gas operated.

An example of what the gas-operated machine gun can do with regard to accuracy, particularly when fired with a heavy barrel, is seen in Fig. No. 3B, which shows a machine-gun shot group from the Colt Machine Gun at a range of 1,000 inches and 2,000 meters. The small group in the lower left-hand corner was made on a vertical paper screen 1,000 inches from the gun. Each square represents one inch. The same shots after passing through the screen formed the beaten zone with the impact of the bullets indicated by markers.

This gun is ideal for accuracy purposes because it is gas operated and has a very slow rate of fire with an extremely heavy barrel. As a consequence, it has very dense dispersion, and what is of far greater importance, it will invariably hold its elevations, as the center line of bore bears a constant relation to sight leaf and clinometer elevation. Therefore, all other things being equal, the design of a machine gun should be such as to embody these desirable features.

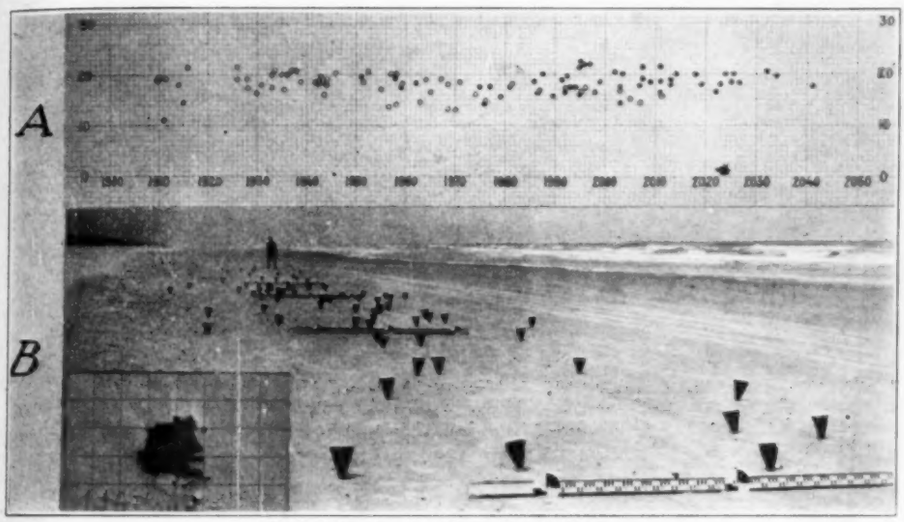


Fig. 3. Machine Gun Dispersion at 2000 Meters
No. 3A. Coinciding Beaten Zones of Two Browning Machine Guns Placed 4000 Meters Apart and Simultaneously Firing Toward Each Other with Elevations Equal to Half the Distance Separating the Guns
No 3B. Smallest Possible Machine Gun Dispersion, Obtained with the Colt Machine Gun and Service Ammunition

Fig. No. 2 also shows machine-gun dispersion at the longest ranges at which it has probably ever been accurately measured. B of this figure gives French Hotchkiss Machine-Gun dispersion with 8-millimeter ammunition, while C, D and E were made by the Browning Machine Gun and a new boat-tailed machine-gun bullet. Due to the greatness of the range all of the shots in the last two bursts were probably not found, so that only a portion of the zone is represented.

How accurately can a machine gun be laid? Well-trained machine gunners, with the Browning Machine Gun, can do precise work. Fig. No. 3A shows the result of a test fired for the purpose of checking the correctness of the elevation, which was finally determined as being the normal elevation for 2,000 meters. Two Brownings were placed opposite each other and 4,000 meters apart, each gun having the normal elevation for 2,000 meters. The two bursts nearly coincide, their centers of impact being separated by only a few yards, neither being at 2,000 meters. However, taking into consideration the wind, one burst should have its center of impact beyond 2,000 meters and the other should be short. This is found to be the case.

Elimination of Metallic Fouling in Rifles

One of the greatest difficulties which American Service Riflemen have to contend with is metallic fouling arising from the use of the standard model of 1906 ammunition. The bullet of this ammunition has a cupro-nickel jacket, and when fired with the standard Pyro powder with which all such ammunition is loaded, it is very prone to leave an uneven deposit of metal in the bore of the rifle, thus destroying its accuracy. The only effective way of removing this metallic fouling which has been found at all practicable is to use the so-called standard metallic fouling solution. This solution has a strong corrosive action on steel, and unless extreme care is exercised, it is liable to permanently injure the weapon upon which it is used, and in fact, many rifles are injured every year from this cause.

In order to do away with metallic fouling and the troublesome use of the solution provided to remove this fouling from rifles, the small arms ammunition furnished by the Ordnance Department for the 1920 National Matches was loaded with a powder in which a small percentage of tin was incorporated during its manufacture, it having been found both in the case of cannon and small arms that a small percentage of metallic tin incorporated in the powder charge eliminates objectionable metallic fouling. However, the question of eliminating metallic fouling without at the same time introducing other objectionable features, such as decreased life of barrel, is still in its infancy, but the next two or three years should see an entirely satisfactory solution of the problem.

Evolution of the Artillery Wheel

By

D. A. GURNEY

Member A. O. A.

THE use of the present type of artillery wheel dates from the adoption of the Archibald type of wheel on the 3.18-inch iron gun carriage in 1881. Prior to that time the wheels used on artillery materiel had wooden hubs, spokes and felloes of the commercial type, still used to some extent on farm wagons, etc. The distinct features of the Archibald type of wheel are the hub construction, consisting of an inner flange integral with the hub box and and outer flange fitting around the cylindrical portion of the hub box and secured to the inner flange by bolts passing through the spokes, and the triangular metal dowels used at the joints of the felloes. The wheel used on the 3.18-inch iron gun carriage was 57 inches in diameter, had a tire width of about 3 inches, and 12 spokes. The felloe was made up of 7 sawed sections, and the total weight was about 180 pounds. The wheel was secured to the axle by means of a linch pin. This type of wheel was definitely adopted as the result of a series of tests by the Board of Light Artillery Officers, the report being dated April 28, 1881. The following claims were made by the Archibald Wheel Company as to the advantages of this type of wheel.

(a) Every joint in both spokes and felloes is pressed together with such force and accuracy that the wheels will stand always in any climate.

(b) Each wheel is put together with a pressure 25 times greater than any weight it will have on it afterwards, and consequently it cannot be crushed by overloading.

(c) On account of this pressure the spokes can never work in the hub, nor can any moisture get within the hub to rust it or rot the spokes.

(d) They will stand more abuse and climatic changes than any other wheel.

(e) Hub box can be replaced readily.

(f) On account of the peculiar dowel used, the spoke can be replaced easier than with any other wheel.

The standard artillery wheel now used on all light artillery carriages and vehicles is a development of the original type of wheel above referred to, and while it has been greatly modified and improved, it still retains the distinctive features of the metal hub box described above and the triangular metal dowels. Numerous changes have been made in the design of this wheel since its adoption with the idea of making it stronger and more serviceable, and of keeping its weight within a reasonable limit.

The more important of these changes are enumerated in detail below. In 1889 a comparative test was run of light and heavy wheels of this type, as a result of which the light wheels failed in the test. The weight of the wheels tested and adopted was about 188 pounds. In 1892 the wheels then used on the 3.2-inch gun carriage developed serious defects in the arrangement of the linch-pin washer and the hub-ring nut. The linch-pin washer was found to rotate with the wheel, producing wear, so this washer was modified by adding a stud, which prevented its revolving with the wheel. The hub-ring nut unscrewed at times and jammed the wheels between the linch-pin and the shoulder of the axle, accordingly it was secured to the hub box by a spline screw. The wheel used on the 3.2-inch gun carriages was 57.75 inches outside diameter with 2.75-inch tires, had 8 sawed felloes, 16 spokes, and was lubricated by applying grease to the axle arm with a paddle.

In 1898 the Ordnance Department undertook the design of an experimental 3-inch gun carriage. In order to lighten the wheel the tire and felloe widths were reduced .25 inch and the felloe thickness from 2.875 inches to 2.25 inches. The thickness of the hub flanges was reduced from .75 inch to .5 inch for the outer flange, and from .75 inch to .625 inch for the inner flange. A change was also made in the felloe to make it of 2 bent sections. The method of fastening was changed from a linch-pin to a nut screwed to the end of the axle, and the wheel was lubricated from an oil chamber in the hub. In 1900 the wheel was changed to 56 inches outside diameter and 3 inches tire width, which is the same as the present steel-tired wheel. This wheel was used on the experimental short recoil 3-inch gun carriage. The tire thickness was reduced to 7/16 inch and the felloe thickness to 2 1/16 inch. The diameters and thicknesses of the hub flanges were also reduced. The wheel was secured by means of an inside wheel fastening similar to that shown in Fig. 2, and was lubricated from an oil reservoir in the axle.

In 1902, for use on the 3-inch gun carriage, Model of 1902 (long recoil), the outside diameter of the wheel was reduced to 48 inches and the felloe thickness to 1.75 inches The diameter and thickness of the hub flanges was also decreased, and the number of spokes was changed from 16 to 14. The weight of this wheel was 142.5 pounds. As the result of road tests of the experimental carriage and limber, it was decided that 48-inch wheels were too small. Due to their relatively poor showing in the road trials, a report was made that increased tractive force and consequent horse fatigue were necessary consequences of the reduced size of the wheels. In view of this fact, the wheels were changed in July, 1902, to 56 inches in diameter, the felloe thickness was increased to 2.125 inches and the tire thickness reduced to .375 inch. In December, 1902, the hub cap was modified by adding the oil valve as used at present. In March, 1904, the number of spokes was increased to 16. In April, 1905, the tire thickness was increased to .5 inch, and the hub flanges were increased in thickness. In July, 1906, the tire thickness was again reduced to 7/16 inch, and the felloe thickness was increased to 2.875 inches. In September, 1906, the tire thickness was again increased to .5 inch, which is its present thickness, and the felloes were changed to permit the optional use of 8 sawed felloes or 2 bent ones. In July, 1908, the outside wheel fastening, as shown in Fig. 2, was adopted. In July, 1912, the diameter of the hub flanges was increased 1 inch. The weight of the wheel at this time was about 185 pounds. In March, 1916, a change was made to prescribe bent felloes, and at about this time the tire steel was changed to high carbon steel, having 50,000 pounds per square inch elastic limit instead of 35,000

pounds per square inch, which had been previously prescribed.

In June, 1917, as a result of test, spoke shoes were adopted, and in August, 1917, the spoke section was increased to improve the design of the spoke shoe. The weight of this wheel, which is the present steel-tired wheel, is about 209 pounds.

During the development of this wheel many tests were made to ascertain the effect of proposed changes. In 1905 an exhaustive series of tests was made on the strength of wheels having 14 and 16 spokes, each with tires of varying thickness assembled with different amounts of dish and with several types of hub. The general scope of the tests was such as to include wheels intact and the elements of strength which contribute to the formation of a strong combination with lightness of construction. Caissons and limbers equipped with the wheel as developed at that time were road-tested for 6 months to a distance of about 1,000 miles. These tests were very severe, the vehicles being overturned, maneuvered at rapid gaits over obstacles, etc. At the end of the test the wheels were in excellent condition.

Tests were ordered in May, 1916, of 36 wheels which were made up specially and issued to the service. Twelve of these wheels had high carbon steel tires and grease-cup lubrication; 12 had high carbon steel tires, grease-cup lubrication, felloes reduced to 2.375 inches thick and were equipped with spoke shoes; and 12 were the same as the last 12, except that they had a dish of .875 inch per foot of diameter instead of .25 as has the standard wheel. This test was not entirely completed, due to the Mexican trouble and the outbreak of war. Report was, however, received from one battery, and it was recommended that the grease-cup system of lubrication be not used. The wheel having the large dish, carbon steel tire, bent felloe and spoke shoes gave the most satisfactory service. The vehicles on which these wheels were tested were provided with tire brakes; and, due to the large dish, the brake shoe bore only on the inner portion of the tire. Due to this fact, the dish of the wheel was not changed, but the other features were adopted for war manufacture.

Numerous tests have also been made of wheels of cast steel, pressed steel, and with steel spokes and steel rims. None of these wheels has been found as satisfactory as the service wheel. They are in general considerably heavier, and failure occurs after a short road test. Good results were, however, obtained with a wheel for heavy artillery, having wooden spokes and metal rims. This type of wheel could possibly be developed for light artillery, although it might be heavier than the service wheel.

As artillery wheels are subject to very severe service, dish is given to the spokes to place them in better position to withstand side blows and side pressure caused by making sharp turns at rapid gaits. The dish of a wheel is generally expressed in inches per foot of radius of the wheel. The dish of the standard artillery wheel is ¼ inch per foot of radius and corresponds to an angle of approximately 1° 12′. One-half of this dish, or 36′, is obtained by making the hub flanges conical, and the other half of the dish by

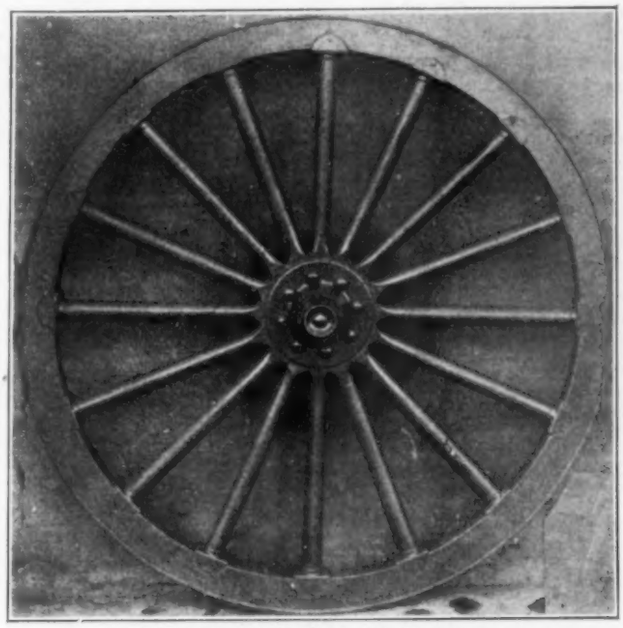


Fig. 1. The Standard 56-Inch Artillery Wheel

bending the spokes when the tire is shrunk in place. This latter part is called the "spring dish." One advantage of the spring dish is to assist in taking up shrinkage of the wooden parts of the wheel, since the spokes tend to return to their original straight position. In order to bring that spoke, which is in contact with the ground, into vertical position when the gun is fired, the axle arm is inclined downward at an angle of 1° 12′. This inclination of the axle is called "set." The bottom element of the axle arm, which supports the traveling load in the hub box, must be horizontal in order to prevent longitudinal thrust of the wheel on the wheel fastening or on the shoulder of the axle. This is accomplished by making the axle arm conical to the same angle as the angle of set. This conical shape of the axle arm also facilitates the assembling and disassembling of the wheel. The seat for the spoke in the wheel hub should be, as nearly as practicable, normal to the axis of the spoke; that is, this seat should be a cone instead of a cylinder, in order that the thrust of the spoke should be as

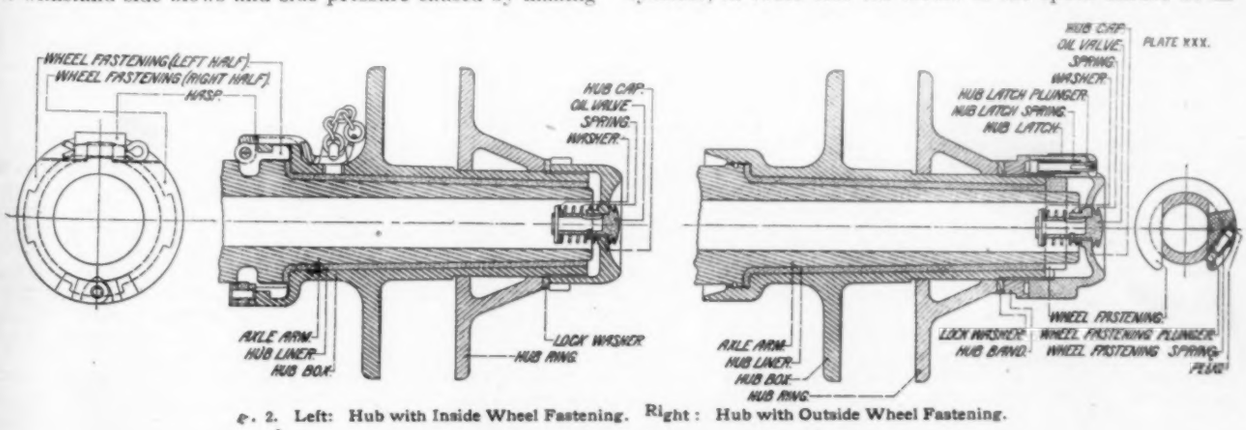


Fig. 2. Left: Hub with Inside Wheel Fastening. Right: Hub with Outside Wheel Fastening.

nearly normal to the surface of the hub as possible, and that the hub might be removed from the spokes easily in the case of making replacements.

For manufacturing reasons it is desirable that the tire should be a true cylinder in the finished wheel. This, of course, causes the wheel to rest on the outer edge of the tire only when the vehicle is on a perfectly level platform, but for road conditions no practical difficulties are experienced with this construction. The felloe is made of rectangular section, well rounded at the inner corners.

The greatest improvement which has been made in artillery wheels in recent years is the addition of the spoke shoe. Prior to the adoption of the spoke shoe a great deal of trouble was experienced with the wear and breakage of the tenons of the spokes in the felloes and in the crushing of the wood of the felloe by the shoulder of the spoke. The spoke shoe provides greatly increased bearing between the spoke end and the felloe, and eliminates practically all wear at this point; also the felloe is strengthened, due to the fact that the hole for the spoke tenon is not required. With the design of spoke shoe adopted, it is a comparatively simple matter to replace broken spokes in wheels without the necessity of removing and resetting the tires.

The lubrication of artillery wheels is very important, since they are required to run for long distances with very little attention. The method of lubrication used on the standard artillery wheel is accomplished by providing an oil reservoir in the axle which is filled through an oil valve in the hub cap, and this filling can be done without removing the wheel. The oil from this reservoir gradually seeps out around the end of the axle and back on to the bearing surface; dust is excluded from the bearing by the use of a leather and sheep-skin dust guard strapped to the axle at the inner end of the hub box.

While the standard 56-inch wheel (Fig. 1) is, in general, satisfactory for use at the highest speeds which may be expected with horse-drawn artillery, this wheel cannot be expected to give satisfactory service when the artillery is drawn behind motor trucks or high-speed tractors, unless the vehicles are spring supported. In order to provide a wheel which would be suitable for this high-speed service the 56-inch wheel has been cut down to 52 inches outside diameter and equipped with a 3.5-inch solid rubber tire, making the outside diameter 57 inches. This wheel weighs about 368 pounds and is known as the 57 by 3½-inch rubber-tired wheel. It is standard equipment for 75-mm. Gun Carriages, Model of 1916, Motorized. The hubs of these wheels and the general construction are identical with that of the standard 56-inch wheel.

For the new divisional split-trail carriages, a wheel of this same construction, but 48 inches in diameter with a 4-inch rubber tire, is being furnished. This wheel weighs 296 pounds. For the new divisional box-trail carriages, 75-mm. Gun Carriage, Model of 1921, and 105-mm. Howitzer Carriage, Model of 1921, this wheel has been reduced in weight by equipping it with a 3½-inch rubber tire, decreasing the thickness of the steel tire or felloe band, reducing the felloe thickness to 1.5 inch, and cutting down the spoke sections and the thickness and diameter of the hub flanges. This latter wheel weighs 233 pounds complete with rubber tire. It has not been tested as yet, and, consequently, it is not known whether it will be satisfactory. It is thought that, due to the resiliency of the rubber tire, it may be strong enough, notwithstanding the considerable reduction in weight.

In view of the great difficulty experienced in obtaining satisfactory wood stock for artillery wheels during the recent war, it is very desirable to develop all-metal wheels for artillery purposes. This trouble has been solved in the case of the wheels used on Corps and Army Artillery, but no satisfactory solution of the problem for light artillery wheels has as yet been found. Various types of metal wheels have been experimented with, including the so-called resilient wheel, which depends for its action upon the use of springs, but none of the wheels tested possess the serviceability and shock-absorbing qualities of the wooden wheel. It is hoped at some time in the future to undertake the development of an all-metal wheel for this purpose, but, due to reduced appropriations and the press of other development work, this is not practicable at present.

Flashless Powder

The elimination of the muzzle flash from guns is one of the important problems of the Ordnance Department of the Army. The use of smokeless powder has eliminated the enormous clouds of black smoke which formerly enabled the enemy to readily "spot" the location of large gun emplacements in daylight, but there still remains the flash, which at night makes "spotting" a simple proposition. Some idea of the size of the flash from large guns can be gained from the fact that in proving ground work, the ropes from which the velocity screens were suspended 100 feet from the muzzle of a 16-inch gun were actually ignited and burned by the flash.

A 14-inch 50-caliber gun fires a shell weighing 1560 pounds with a muzzle velocity of 2650 feet per second, with a charge of 460 pounds of smokeless powder. The shell is propelled from the gun by the rapid conversion of the powder into gases at a high temperature and pressure. It is calculated that the gas evolved from the 460 pounds of powder has a temperature of 2240 degrees C. (4064 degrees Fahrenheit), and if it could expand at atmospheric pressure at this temperature, would occupy a volume of 63,457 cubic feet. This gas is a mixture, the chief components of which are carbon monoxide, hydrogen, carbon dioxide, nitrogen and water vapor. The first two components are combustible gases and constitute about 56 per cent of the entire volume. There is, therefore, over 35,000 cubic feet of inflammable gases at a temperature of incandescence issuing from the muzzle where it immediately ignites on coming in contact with the oxygen of the air. The enormous flame produced can be seen for miles at night and illuminates all surrounding objects with its brilliant glare. Even in 75 mm. guns the flash is brilliant and blinding.

Experimental work, with the object of reducing or eliminating this flash, has been carried on in this country mainly since 1917, although the first efforts in this direction date back to 1910. Night firings have recently been made with guns as large as the 5-inch gun, in which the muzzle of the gun was barely visible to observers 50 feet from the gun, the brilliant flash being reduced to nothing more than a momentary dull red glow with no illumination whatever. These remarkable results are produced by the application of the same principles by which blasting explosives are made safe for use in gassy coal mines; by the addition of various substances to the smokeless powder charge for the purpose of cooling the gases of explosion to such a temperature that they will not ignite when they escape into the air at the muzzle of the gun.

Some of these substances are materials which do not burn but are volatilized, their vapors exerting a cooling effect on the hot gases and serving to dilute them. Common rock salt, for example, merely placed in a separate package along with the powder charge, or thrown by means of a scoop into the powder chamber of the gun, is a very effective flash reducer, but is not always consistent in its effects. Chloride of potash was largely used by the Germans for this purpose.

It is also of interest to note that the *noise* of the discharge of the gun is appreciably less with a flashless charge than with service powder, because of the fact that a large part of the sound is due to the explosion of the combustible gases when they mix with the air and ignite to produce the flash.

It is hoped that the success obtained with the smaller guns will be equalled in the case of the large ones, but the problem is much more difficult.

Roller Bearings for Gun Trunnions

By

F. BRAUER

Member A. O. A.

ON gun carriages where the weights of the gun and cradle, or, as they are commonly called, the tipping parts, are not excessive, the trunnions of the cradle rest in bronze bearings in side-frames or top-carriages. Where the caliber of gun is 8 inches and over, it is necessary to introduce mechanical means by which the elevation and depression can readily be accomplished in the shortest possible time.

Several methods have been devised to obtain this result. One method, used by the Army Ordnance Department, is to carry the weight of the tipping parts on small outer trunnion bearings, one on either side of the main trunnion. These, by virtue of their size and better bearing combination, make it easier to elevate and depress the gun. By means of levers supported at one end on a steel fulcrum bolt carried in a fulcrum bracket on the top-carriage side-frame and at the other end by a plunger which bears against a hardened steel bearing block inserted in the bottom face of the lever, as well as by the introduction of Belleville washers, the trunnions will float under the dead load of the tipping parts; but when the gun is fired the increased load compresses the springs, causing the large trunnions to bottom in their bearings and take the heavy firing load.

Another method, used by the Navy Department in order to minimize friction when elevating or depressing the gun, is to so arrange the trunnion bearings that the trunnions can be raised just clear of the main bearings by means of wedges operated by differential screws. A stud is inserted in the end of each trunnion of the cradle, which stud rests on the trunnion float, and each float rests on 16 steel rollers supported by the upper wedges. The trunnions of the cradle have generally a clearance of .02 inch in the trunnion bushings, and when the lower wedge is drawn to the rear by the differential screw, the upper wedge is forced upward and the trunnions will then be supported entirely by the trunnion floats. When the cradle is elevated or depressed, these trunnion floats will move forward and backward on the roller bearings, thus substituting rolling friction for the sliding friction which would occur if the trunnions rested entirely on the bushings.

In the heavier materiel recently designed by the Army Ordnance Department, instead of using either of the methods described above to eliminate journal friction and reduce the resistance in elevation and depression to the very minimum, large roller bearings have been provided in each trunnion. By the introduction of levers and fulcrums and Belleville springs in conjunction with these roller bearings, it is possible to manipulate, with perfect ease and in a short interval of time, tipping parts weighing 500,000 pounds, as in the case of the 16-inch Barbette Carriage, Model 1919.

The arrangement of the roller bearings with lever springs and the connecting link between the roller bearings and the levers called crutches are very clearly shown on the accompanying illustrations, Fig. 1.

The purpose of this article is not so much to review the different methods of anti-friction devices used in gun carriage construction, as to publish results of tests made of the large roller bearings designed for the 16-inch Barbette Carriage, Model 1919. In order to determine by actual tests whether it was possible to manufacture bearings which would stand the strain that would be brought upon them, there were devised at Watertown Arsenal fixtures which were placed in the testing machine, and by inserting roller bearings which had been procured for the 16-inch Barbette Carriage, it was possible to subject these to even greater

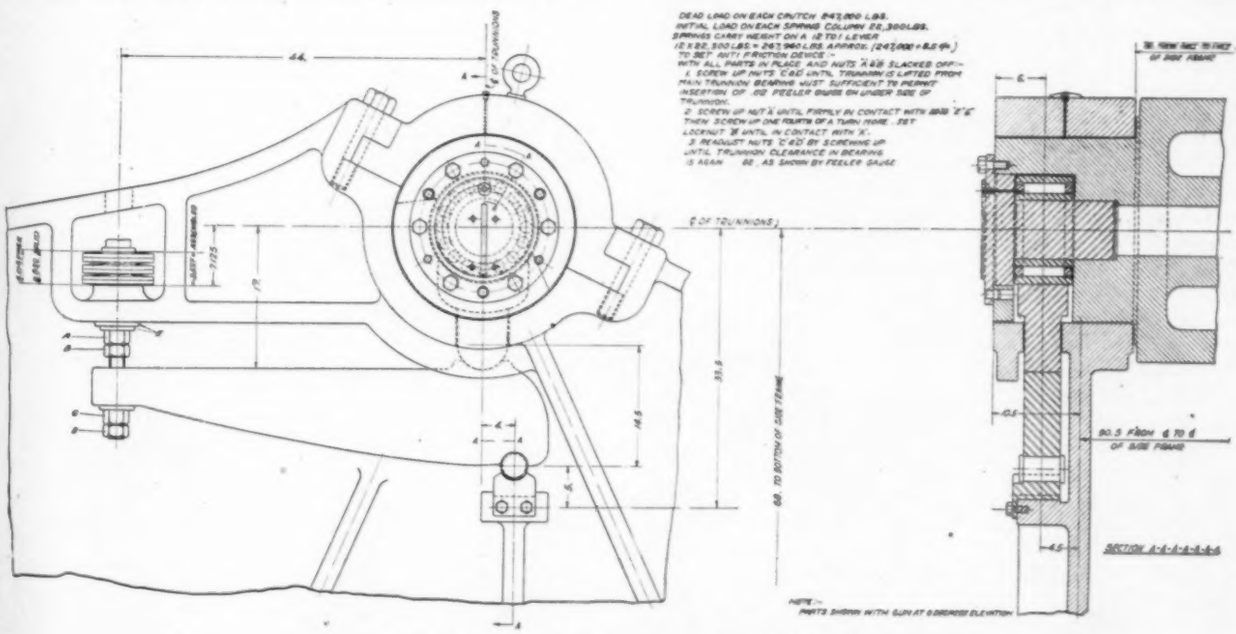


Fig. 1. Anti-Friction Assembly for 16-Inch Barbette Carriage

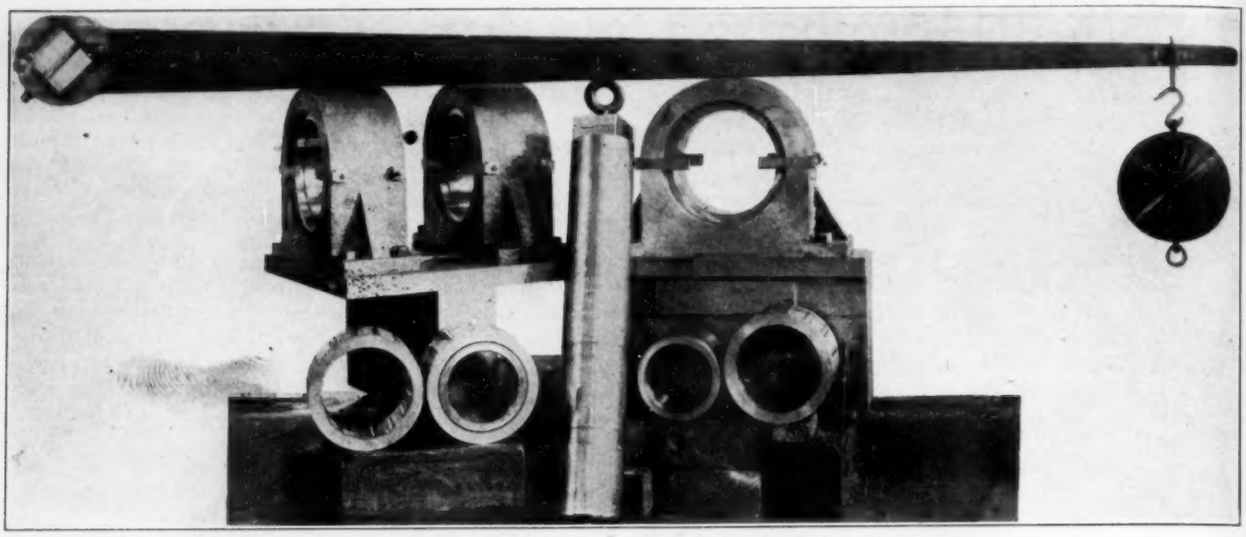


Fig. 2. Roller Bearings and Fixtures Used in Test

strains than would come on them during elevation and depression of the tipping parts.

In the test there were used three pedestals as indicated in Fig. 2. One of the bearings was placed in one head of the testing machine, the two other bearings joined by a plate in the other head of the machne, and an axle inserted through them as shown in Fig. 3. At the end of the axle a 120-inch long lever was attached, at the end of which a spring balance was applied, so that for various increments of loads, by rotating the shaft, the force could be readily ascertained. By using this apparatus a very accurate test of the strength of these bearings under various loads was ascertained.

The roller bearings—that is, the inner and outer sleeves —as well as the rolls were made of chrome nickel steel, the rollers having a scleroscope hardness of 100 or more, and the inner and outer sleeves a scleroscope hardness of between 96 and 100. These bearings were manufactured by the Standard Machinery Co. of Auburn, R. I. The size of the cages, as well as the rolls, is shown in Figure 2. From the data sheet below, it will be noted that the loads were applied by increments of 50,000 pounds and the starting force readings were recorded by means of a large dial spring balance fastened to the lever arm of 120 inches in length. As stated above, this lever fitted over the top of an axle 7 inches in diameter which served as a spindle for the three sets of rollers held in fixtures in the machine.

Although it is not shown in the illustration during this test, a counterpoise was hung on the lever placed at 180 degrees from the 120 inch lever arm so as to balance the "over-hang" of lever and spring balance. As each increment of 50,000 pounds load was applied, the starting force was recorded through an angle of 72 degrees, this being the angle through which this bearing will work when inserted into the trunnions of the 16-inch Barbette Carriage, Model 1919, each movement being from minus 7 degrees to plus 65 degrees. Three readings of the starting force were taken at each angle of 12 degrees, thus making a total of 18 readings for each increment of load applied.

For each increment of 50,000 pounds above 150,000 pounds load, the bearing was taken out, examined and rollers and sleeves or casings carefully measured to detect any deformation which may have occurred. Special care was taken in measuring the rollers which would come directly in line where the force was applied and lying within the 72 degrees service angle.

The observations and measurements during and after the test showed that the rollers and casings were safe for all loads given in this test. Since the maximum of 800,000 pounds applied to the middle roller bearing and 400,000 pounds which would be the reacting force on the two other roller bearings, produced no deformation, whereas the actual static load on these roller bearings when the tipping parts of the 16-inch Barbette Carriage are applied thereto would be 500,000 pounds, or 250,000 pounds at each trunnion, it is the opinion of the officials of the Watertown Arsenal that these bearings were all intact after test and could be used in service with security.

The 120-inch lever used in the test of these roller bearings was selected, because the pitch radius of the elevating rack on the gun carriage for which these bearings are intended was 120-inch radius, and it will be noted from the tabulation below, that if the conditions obtained in the testing machine should prevail also when the tipping parts were assembled on the carriage, that at that distance from the center of rotation it would only take an average of 30.7 pounds to start rotation of the 500,000-pound weight provided this weight was perfectly balanced, coef. of friction being .00092.

While the data obtained of these bearings during the test indicated conditions beyond what was expected, it is not possible that the same conditions will materialize when these roller bearings are inserted into the trunnions of a cradle, due to the fact that in the test the supports for the roller bearings were close to each other, while in the case of a cradle, the roller bearings will be attached to trunnions, which with the insertion of the gun weighing approximately 180 tons, might cause some deflection which cannot be avoided and which would throw any perfectly aligned trunnion and trunnion bearings slightly out of alignment. The fact of the matter is that during the shop trial of these roller bearings when inserted into the trunnions of the cradle of 16-inch Barbette Carriage, Model 1919, with the gun mounted therein, the results obtained justified the adoption of this form of bearings in order to obtain flotation of the tipping parts of heavy Ordnance material.

While the coefficient of friction obtained with cradle and gun mounted was .0093, derived as follows:

$$u = \frac{rTa}{RcW} = \frac{.625 \times 60 \times 620}{5 \times 500{,}000} = .0093$$

u equals coefficient of friction.

r equals radius of rolls.

620 inches equals the distance from center of rotation to muzzle of gun.

60 pounds being the force at the muzzle required for rotation.

5 inches being the distance from the center of rotation to center of rolls.

500,000 pounds being weight of the tipping parts, this difference in the coefficient of friction (10 to 1 from that obtained in the testing machine), while considerable, is due to springing or deflection in the cradle and possibly due to slight inaccuracy in the manufacture in obtaining perfect alignment. Even at that a coefficient of rolling friction of practically .01 is a very acceptable factor.

NOTATION AND FORMULAE

W — Load applied in pounds.
Fa — Average starting force in pounds.
Ta — Average starting torque in inch pounds.
Rc — Distance of center of rollers to center of bearing in inches.
r — Radius of rollers.
u — Coefficient of friction.

$$Ta = 120\ Fa$$

$$\frac{Ta}{Rc} = \frac{Wu}{r}$$

$$u = \frac{rTa}{RcW}$$

Column I	Column II						Col. III	Col. IV	Col. V
Load Applied	Starting force at end of 120-inch lever. Through angle of 72°.						Fa	Ta	u
W	1	2	3	4	5	6			
50,000	3.	4.	4.	3.5	4.	3.	3.5	420	.00105
100,000	4.5	4.	6.	.5	1.	5.	3.5	420	.00052
150,000	3.	5.	5.	.5	4.	3.	4.25	510	.000425
200,000	5.5	9.	9.5	.5	7.5	10.	7.00	840	.00052
250,000	25.3	20.83	9.66	9.60	10.0	6.6	13.70	1644	.00082
300,000	22.	11.	24.	18.66	5.33	14.	15.72	1884	.000783
350,000	19.3	9.67	15.67	14.	11.4	12.67	13.8	1656	.00059
400,000	27.5	22.17	15.17	20.67	17.	13.67	19.36	2316	.00072
450,000	24.33	19.50	18.50	22.30	17.33	23.0	20.83	2496	.00069
500,000	34.67	23.0	26.67	40.33	32.0	27.3	30.7	3684	.00092
550,000	35.0	35.3	42.0	40.3	32.0	37.0	36.9	4428	.00101
600,000	37.0	42.3	53.67	37.0	47.0	48.7	44.3	5316	.0011
650,000	46.3	48.67	77.0	60.3	52.0	50.3	55.7	6684	.00129
700,000	78.67	82.0	83.67	83.67	85.3	80.3	82.27	9872	.00176
750,000	107.0	95.0	105.5	104.5	125.0	87.0	103.9	12480	.00208
800,000	122.0	142.0	172.0	151.0	157.0	122.0	144.3	17316	.00270

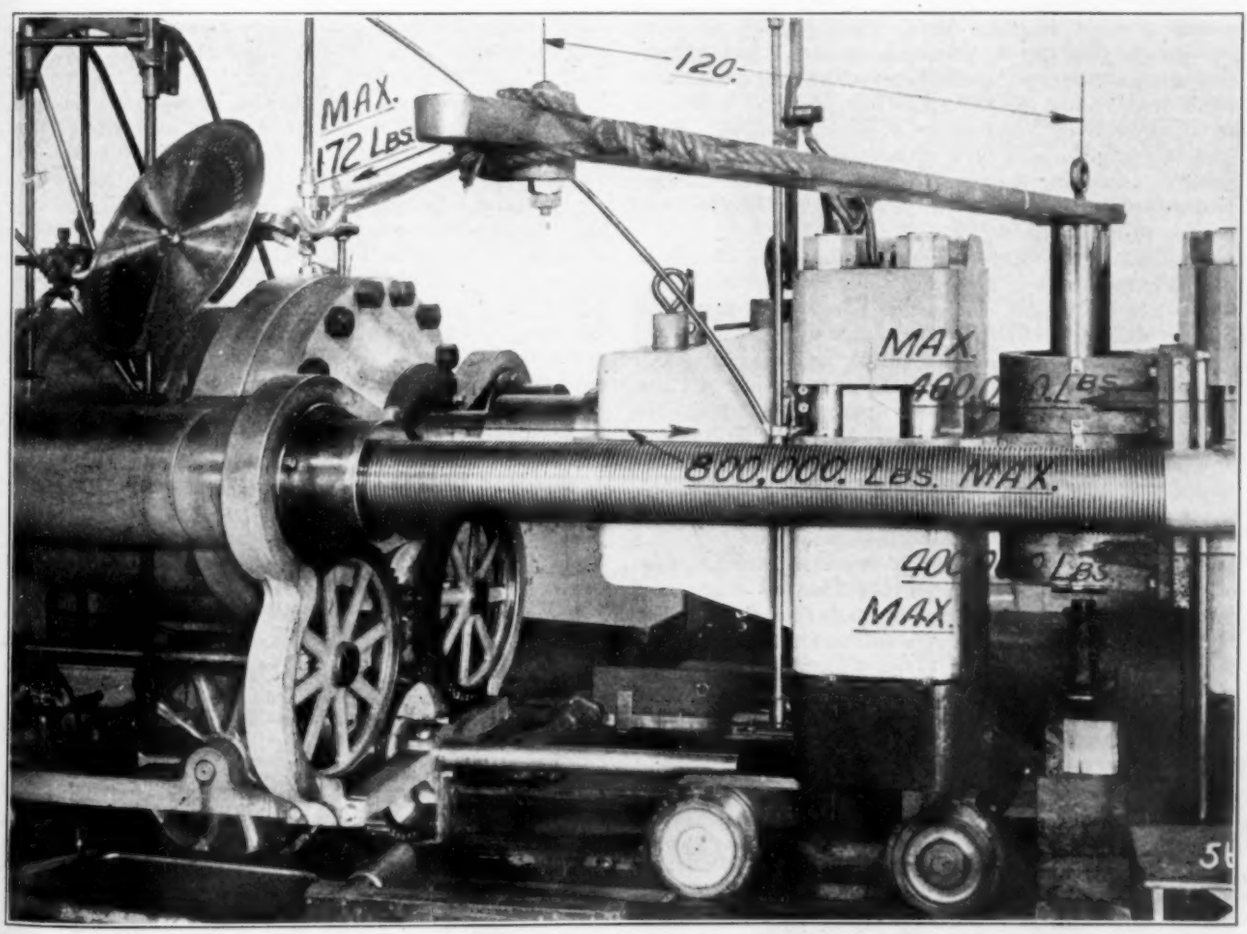


Fig. 3. Arrangement of Apparatus in Testing Machine

ARMY ORDNANCE

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Bombs heard 'Round the World

ON witnessing the sinking of the ex-German battleship *Ostfriesland* by 2,000-lb. demolition bombs manufactured by the Army Ordnance Department and dropped from airplanes manned by the Army Air Service, General Williams, Chief of Ordnance, aptly remarked: "A bomb was fired today that will be heard around the world."

As a result of the mimic combat staged between bombs and battleships, General Williams further remarked, "The capital ship now faces a new menace which must be guarded against by every possible study and effort." It is doubtful if the results of the test and the lessons to be learned therefrom could be summed up in fewer words or stronger phrases.

The incontrovertible facts of the case are that a modern airplane can be flown at least 100 miles to sea and can, by dropping a modern high explosive bomb, sink a modern battleship.

The menace of the airplane bomb can never again be disposed of by academic discussion—nor by ridicule. Naval architects the world over must bear constantly in mind the results achieved in these tests. They can no more be waved aside than can the submarine menace. In the swiftness of its attack and the deadliness of its stroke, the aerial bomb far exceeds the submarine torpedo. In radius of action alone is its effectiveness at present limited. However, expansion of its field of operation can be attained either by increasing the present cruising radius in building future bombing planes or by providing airplane carriers for the present planes.

The limit of effectiveness of the bomb proper has not as yet been reached nor even approached; 4,000-lb. demolition bombs of 100 per cent greater effectiveness than those used to sink the *Ostfriesland* have already been developed by the Army Ordnance Department, and the Army Air Service is convinced of its ability to transport them through the air and drop them accurately on designated targets. The first of these super-bombs will, in fact, be dropped at the Aberdeen Proving Ground in the near future during the Third Annual Meeting of the Army Ordnance Association.

The best protection of the battleship appears to lie not in structural improvement but in provision for auxiliaries of the air—airplanes accompanying fleets to engage and ward off hostile bombing squadrons. Anti-aircraft batteries on battleships may be of assistance, but they have yet to demonstrate their ability to wholly prevent determined air bombers from approaching at least near enough the target to drop bombs creating sufficient mine effect to open the seams of any battleship as yet constructed, even if no hits whatever are registered upon the ship itself.

Great results are seldom obtained without great effort. While spectacular feats of flying airplanes far to sea are deserving of the highest praise, the long tedious work of computing bomb ballistics, the solution of the intricate problems of designing bomb sights in conformity thereto, the pioneering, dangerous work of manufacture are equally important and equally deserving of appreciation in developing new means for our national defense. Air Service officers did a very gracious thing in so promptly expressing their appreciation of the indispensable part played by the Army Ordnance Department in creating the instruments which so vastly enlarged the power of the airplane in combat with the battleship.

Disarm *and* Die

ENTHUSIASTIC supporters of the "Disarm *or* Die" theory, who believe that Germany is the sole beneficiary of the Treaty of Versailles through those provisions which were designed to leave her bereft of all aggressive military power but which, they aver, have in reality but conferred upon her vast and unexpected economic power, and who believe that all nations must similarly divest themselves of all means for defense or be submerged, overlook the fact that the World War did not wipe out conflicting national ambitions nor international jealousies and suspicions. France has derived no assurance of security from the results of the World War; twice invaded by Germany within the memory of living men, the black pall hangs menacingly over her still. The French are practical people and use the light of the past to peer into the future. What has happened twice recently may occur again in the future. Treaties are written on no more durable medium today than when the famous "Scrap of Paper" was so easily rent asunder by those whose interests lay in ignoring its provisions.

Universal disarmament presupposes a desire on the part of all concerned to settle contentious questions on a basis of right and justice, but most nations today want questions settled on a basis giving them a favorable advantage over their opponents. Western powers demand equal opportunity in the Far East, but do not hesitate to deny Far Eastern peoples equal opportunities in Western countries. The great powers of the world, America included, demand the "Open Door" in China, but flatly deny equal and similar rights to China within their respective boundaries. America stands ready to maintain the Monroe Doctrine in the Western Hemisphere even by force of arms, but is unwilling to subscribe to a similar doctrine in the Orient. America complains of Japan's aggressive intentions toward China but blandly ignores actions at least as aggressive by other powers in China. America professedly seeks to avoid being involved in European politics as such, but calls a conference to consider problems of the Pacific, which cannot fail to involve her in European politics indirectly.

We are not alone in our professed desire for right and justice. All nations presumably tell themselves that they are but seeking right and justice, although what they consider right and just may well be directly opposed to what we so consider. In the absence of effective means to maintain our own contentions as to right and wrong, and in offering to submit our destinies to the dictum of nations whose interests are directly opposed to our own, may it not well be that Disarm and Die would be for us synonymous terms?

Industrial Preparedness

Industrial Preparedness, to the furtherance of which our Association is dedicated, appears at last to be coming into its own. With the formation of an Ordnance Section of the Society of Mechanical Engineers, which held an enthusiastic professional meeting at Rock Island Arsenal last spring, and offered to place its entire resources at the disposal of

the Army Ordnance Department in the solution of engineering and production problems, and plans under way for participation by this Society and also the Ordnance Section of the Society of Automotive Engineers in the Third Annual Meeting of the Army Ordnance Association, the lesson is being slowly and, we hope, surely learned that Industrial Preparedness is the bed rock of our whole structure of preparation against attack. Certainly American science, engineering and industry are beginning not only to understand the tremendous tasks which will devolve upon them in the event of war, but are likewise beginning in no uncertain tones to demand that they shall be given their rightful opportunity to prepare for their wartime duties.

With the organization of an efficient directorate of munitions in the War Department under the direct supervision of the Assistant Secretary of War, and the detail of a considerable number of officers to study all phases of basic raw material supply and production possibilities of "key" industries, the day is passing when the War Department took for granted the prompt supply of Ordnance and munitions of war and considered its duty fulfilled when "manpower curves" to which supply departments were directed to conform were approved. Of even greater significance as indicative of newly aroused interest within the Army itself is the announced intention of the *Army and Navy Journal* to establish a department devoted to industrial mobilization. The new editor of the Journal, Brig. Gen. Henry J. Reilly, Illinois National Guard, a graduate of the Military Academy and World War Commander of the First Illinois Field Artillery, states in a recent issue entitled "Industrial Mobilization":

> Along with the great American fallacy that we can raise an Army overnight is the still greater but more modern one that we can turn out the armament the next day. We cannot understand that in order to have effective industrial mobilization in war we must have industrial preparation in peace. The editor had his eyes opened to how much greater extent industry plays a vital part in war than has ever been the case before when visiting the British and French fronts as far back as 1914 when the British lacked shells and the British and the French both had an insufficient supply of heavy field and machine guns, and they both entirely lacked hand grenades and trench mortars, while the enemy had all these weapons. When he visited England in March, 1915, and saw to an even greater extent than in France, which had been much better prepared, the tremendous effort being made and how long it took to really mobilize industry for war, impression was made which will never be forgotten. Last summer when with the Polish army in the Kief campaign and later with the Vistula campaign in which the communists were decisively defeated, he had borne in on him day by day while watching the fighting how the lack of modern industry which could supply the essential weapons and their projectiles weakened an Army. The battlefields of these two campaigns were more like those of the last century than the ones of modern war. A single first-class combat division properly armed and supplied could have torn its way through either the Russian or the Polish army at any time. For this reason it is the intention to constantly maintain a department in the JOURNAL under the heading of Industrial Mobilization.

In spite of the agitation for approximate or complete disarmament, it is probable that the subject of Industrial Preparedness is being more widely discussed to-day than at any time since the Armistice. Significant of this condition of affairs is a splendid article by Grosvenor B. Clarkson, late Director of the Council of National Defense, from which we quote a few passages below, and concerning which the Editor of the American *Review of Reviews* comments as follows:

> However distasteful the idea of war may be, the army and navy will not be serving the cause of peace by clinging to obsolete weapons. We are publishing this month a very trenchant article from the pen of Mr. Grosvenor Clarkson reviewing certain of our experiences in the recent war, and calling attention to the necessity of keeping alive our plans for marshalling the industries of the country for defense in case of future emergency. The training that was given to more than four million young men in the year 1918 gives us a reserve strength so far as man-power is concerned that will be available for a good many years to come. But wars require the services of industry on a stupendous scale, and there were lessons learned in 1917-18 that it might be disastrous to forget. Congress should not fail to support a suitable plan for bringing the nation's industrial forces into quick action if the necessity should arise. There is nothing more wasteful than the "scrapping" of accumulated stores of knowledge and experience.

Some of Mr. Clarkson's most forceful paragraphs are:

> The majority of persons still think of war only in terms of troops and waving flags. They still think that appropriating for an army and navy ends the duty of Congress. It is not true. Modern war means the linking of industry and science to the military needs, and, lest there be almost criminal waste of money and loss of life, the linking must be arranged for before and not after the actual need. In armed conflict to-day there can be no preparation when the fight is on, for preparedness now is a scientific thing, and scientific application precludes haste.
>
> Modern war—and every American should get this well into his head—means, in its practical working, the utilization of all of the industries in one form or another, to say nothing of the lay citizenship of a country.
>
> * * * * * * *
>
> Howard Coffin, that automobile engineer out of the West who was the pioneer protagonist in this country of industrial preparedness, has said:
>
> "Twentieth-century warfare demands that the blood of the soldier must be mingled with from three to five parts of the sweat of the man in the factories, mills, mines, and fields of the nation in arms."
>
> * * * * * * *
>
> The other day the newspapers stated that the Council of National Defense, created by Congress as a permanent body ten months before we went to war, and the only body at present on the statute books charged with attending to these matters, was denied by Congress an appropriation for its operation after June 30, 1921. It seemed to be a startling evidence of the lethargy of the times as to our national destinies, of the fact that reactions from the war have made the pendulum swing too far back.

Election of Officers

At the annual election of officers and directors, polls for which were closed on Tuesday, September 6, 1921, Hon. Benedict Crowell was re-elected President for the ensuing year and Mr. W. W. Coleman was re-elected Vice-President. Guy E. Tripp, Samuel McRoberts and Waldo C. Bryant were re-elected Directors to serve for the two years ending September 30, 1923. Robert P. Lamont, Frank A. Scott and C. L. Harrison, who last year were elected Directors to serve two years, will of course continue to serve during the ensuing year also.

Third Annual Meeting

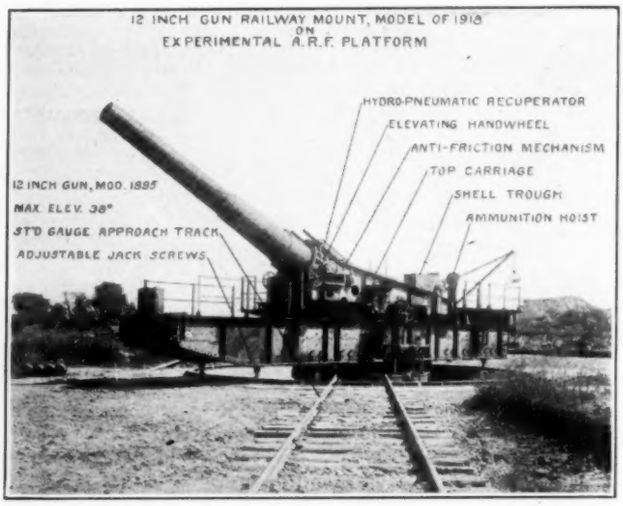
Under authority of the Secretary of War, the Third Annual Meeting of the Army Ordnance Association will be held at the Aberdeen Proving Ground on Friday, October 7, 1921. The Chief of Ordnance has invited the American Society of Mechanical Engineers and the Society of Automotive Engineers to visit the Proving Ground on this date and participate in the meeting. Full details of the meeting, including program of firings, etc., are printed on the first two pages of this number of ARMY ORDNANCE, arranged to be torn out and preserved for ready reference. Additional information will be furnished on application to the Secretary, Room 410, Munsey Building, Washington, D. C.

A. O. A. members are urged to make prompt application for identification badges and meal tickets, as the limited accommodations of the Proving Ground will be taxed to the utmost in caring for members of the three societies invited to be present.

Artillery Division Notes

"All-around Fire" Platform for 12-Inch Railway Mount.—The manufacture of a number of 12-inch railway mounts, model of 1918, was undertaken by the Army Ordnance Department during the World War for use abroad. At the signing of the Armistice, these mounts were so far along that the Secretary of War directed their completion. This carriage which is described in detail in Ordnance Pamphlet 2020, mounts the 12-inch gun, model of 1895.

The maximum range of the gun with a 700-pound projectile is 29,000 yards at 38 degrees which is the maximum elevation permitted by the carriage. Each mount is provided with two ground platforms carried in special cars. A trained crew with the aid of the special car and its equipment can lay the



platform in about two hours. The platform does not permit any traverse of the gun, but a total of ten degrees traverse can be obtained by means of the top carriage. Although this ground platform is a very satisfactory type for use against stationary targets it is not suitable for seacoast defense purposes due to the limited traverse which can be obtained.

The value of a platform for this mount which would permit the carriage to be rapidly traversed through 360 degrees is apparent. One has been devised by making use of the base ring, rollers and racer pertaining to a 10-inch Disappearing Carriage, Model of 1896. A number of the 10-inch Disappearing Carriages ordered removed from the fortifications by the Secretary of War were to have been disposed of as scrap and therefore are now available for this purpose.

The base-ring of the 10-inch Disappearing Carriage, Model of 1896, is used without any modification. It is secured by foundation bolts to a concrete block of sufficient size to withstand the firing stresses. This base ring forms the path for the rollers which support the steel racer. All parts which were originally attached to the racer are removed. Two large filler beams are bolted across the top of the racer and so spaced that when the mount is placed over the racer the bottoms of the girders will rest upon these beams. The bottom flanges of the girders are clamped to the beams by means of clips and bolts. Front and rear clips bolted to the racer react against the base ring and prevent the racer from lifting during firing. The platform and mount are traversed by means of the same rack and pinion as used for the Disappearing Carriage. The traversing pinion is connected through gearing to the fast and slow traversing crank and handwheel, which are attached to a steel casting bolted to the top surface of the racer. A 3-inch Telescopic Sight, Model of 1912, is attached by a bracket to this same casting and located conveniently to the handwheel. The load required to traverse the mount by means of the slow motion handwheel is 4 pounds, while the load required at the fast motion crank is 30 pounds.

There is also an outer ring made up of steel segments resting upon a circle of concrete which is integral with the block of concrete upon which the base ring rests. These steel segments securely bolted and keyed together form a base for the screw jacks which are bolted to the girders. The steel segments are provided with leveling screws in order that the upper surface of the segments can be accurately leveled. The four small screw jacks, which are attached to the girders, can be so adjusted in height as to just clear the steel segments. The purpose of this ring is to provide an additional support for the mount during recoil and counter recoil.

The 12-inch mount is modified only to a slight extent to adapt it to this platform, but this modification will in no way interfere with its use with the ground platform first mentioned. The modifications consist of attaching steel plates to the bottom of the girders so located and of such dimensions as to fit into the recesses on the filler beams bolted to the racer. Steel plates with jack seats into which the jack heads bear are attached to the girders. Four simple screw jacks are also attached to the bottom of the girder, to bear against the outer ring as described above.

Preparatory to placing the railway mount on the "All-around fire" platform, the rotating parts of the platform are brought into such a position relative to the approach track that the stop pin may be put in place with a view to accurately aligning the rails of the fixed and movable parts. This prevents the platform from moving while the mount is being put in place.

The mount is then pushed over the platform until the vertical plane through the trunnions is 97.364 inches in front of a vertical plane through the center of rotation. This relation being established, the shear plates on the under side of the girders are in proper position relative to the recesses on the top face of the filler beams. Four 100-ton screw jacks are then placed under the girders in such a position that the jack heads engage with the jack seats on the girders. The four jacks are brought to a firm bearing on the jack seats and the whole mount lifted until it is free of the trucks. All jacks should be simultaneously operated so that the mount will remain level in both directions. The mount is raised until clear of the trucks, which are then withdrawn to a distance well clear of the emplacement. The jacks are now simultaneously lowered, until the bottom of the girders come to a firm seating on the filler beams, after which the girders are clamped to the filler beams by means of the clamps and bolts. The small screw jacks attached to the girder are now run down to just clear the outer ring and locked in position. These jacks should be so adjusted as not to interfere with the traversing of the mount. The stop pin should then be removed, after which the mount may be traversed.

This platform has been tested at the Aberdeen Proving Ground. A considerable number of shots have been fired to date and the platform appears to be entirely satisfactory for the purpose.

Further test of Pilot Mark VII Motor Carriage, Mounting 75 mm. Gun, Model 1916.—The pilot Mark VII motor carriage for the 75 mm. gun, model 1916, which is now at the Aberdeen Proving Ground, Maryland, has been run approximately 1750 miles to date. This motor carriage is equipped with the 8-cylinder Cadillac touring car engine which is, of course, not suited for the heavy duty work which the engine in a motor carriage is called upon to perform. In the engine at present installed in this motor carriage, Kelly metal bushings are used in the crank-shaft bearings. These special bearings have given very satisfactory service and have lasted much longer than the standard bearings ordinarily used in the Cadillac engine.

At the end of approximately 1000 miles of running both tracks on this motor carriage had to be replaced. Due to the severe testing to which this pilot carriage had been subjected, the original set of tracks were very badly worn. The remainder of the motor carriage shows very little sign of wear and in order to obtain data as to the life of the various parts of this carriage it is planned to have this original pilot 75 mm. gun motor carriage accompany the newer models of 75 mm. gun motor carriages throughout all of their maneuvering tests at the Aberdeen Proving Ground, Maryland, as far as the lower speed of this pilot will permit. By this method it is hoped to obtain valuable engineering data as to the merits of the new models of both the Holt and Christie types compared with this original pilot, as well as data as to the life of the different parts of the carriage itself.

Caterpillar Adapters for the 155 mm. Gun Carriage, Model 1918 *(Filloux) and 8-inch Howitzer Carriage, Mark VI and VII.*—There was recently completed at the plant of the Harrisburg Manufacturing & Boiler Company, Harrisburg, Pa., and shipped to the Aberdeen Proving Ground, Maryland, for test, caterpillar adapters sufficient to equip the gun carriages of one battery of 155 mm. gun carriages, Model of 1918

(Filloux) and two batteries of 8-inch Howitzer carriages, Mark VI and VII. The purpose of caterpillar adapters for these two types of field carriages is to distribute the heavy axle load over a greater surface on the ground and thereby permit the maneuvering of these heavy carriages over soft, swampy ground which would be impassable for the regular field carriage provided with the round wheels. These caterpillar adapters, designed in the Office of the Chief of Ordnance, carry out the approved recommendations of the Westervelt Board Program.

The caterpillar adapters are a redesign of those developed during the World War. The truck roller frame, axle brackets and brake mechanism have been redesigned, but the track links, blank sprocket, truck rollers, supporting rollers, roller bearings and other minor parts are standard 10-ton artillery tractor parts.

The internal expanding brake encased within the sprocket is actuated by a cam, which receives its motion from a handwheel through a set of helical gears and a lever connected by a brake rod.

Application of these caterpillar adapters to the 8-inch Howitzer carriages, Mark VI and VII, necessitates removal of the wheels and brake mechanism and replacing with corresponding parts, the axles, axle brackets, traversing pivot and gear box, cover and traversing handwheel and shaft.

Application of the caterpillar adapters to the 155 mm. gun carriage, model of 1918 (Filloux), necessitates the removal of the wheels and brake mechanisms. The axle bracket on these adapters differs slightly from those applied to the 8-inch Howitzer carriages. It consists of two parts, an axle bearing pivot plate bolted rigidly to the roller frame and an axle bracket bolted to and pivoted in this plate, thereby permitting the spreading of the adapters when the mount is in firing position and split trail spread.

Investigation of strength of 240 mm. Howitzer.—The proof firing of the entire number of 240 mm. howitzers of the models 1918 and 1918MI manufactured by the Ordnance Department has recently been completed at the Aberdeen Proving Ground and studies of the results of these proof tests show that a large majority of the howitzers have increased in diameter amounts greater than desired and much more than has previously been experienced with major caliber guns of similar characteristics.

In the analysis of these unlooked for results two new conditions which have heretofore not been considered in the design of cannon from a strength point of view seem to be of sufficient importance to warrant their serious consideration in the future and are offered as an explanation to the enlargement of the howitzers under discussion.

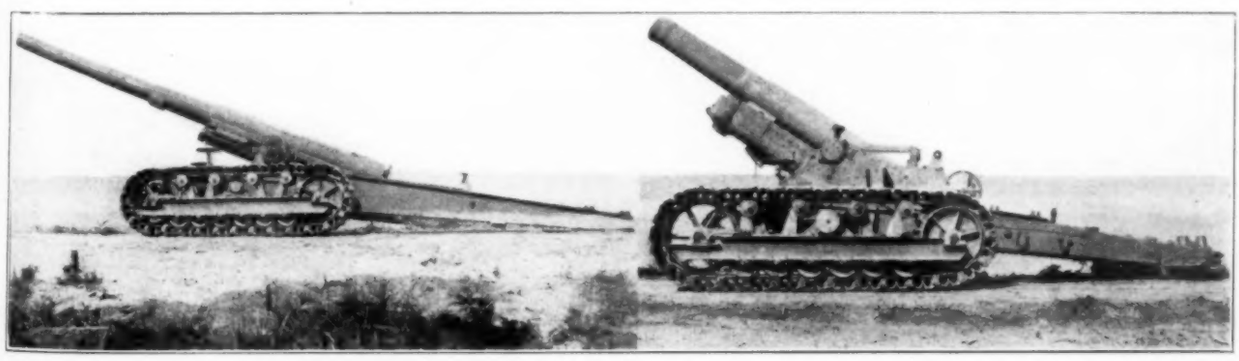
Referring to the accompanying set of curves it will be noted that the powder pressure for full charge based upon Le Duc's formula is represented by Curve B while Curve E shows the tangential resistance using an elastic limit as specified for the several component parts of the piece. The ratio of these two curves is the factor of safety at the several points and is represented graphically by the Curve H. It will be seen from this latter curve that the minimum value of 1.29 exists at the breech with a gradual increase towards the muzzle to a value of approximately 2 with one low point at the end of the jacket where it is about 1.32. From a study of this curve it would be expected that the enlargement, if such was taking place, would be at the breech end with a gradual decrease towards the muzzle but such is not the case, for in the hundreds of howitzers tested none have shown any appreciable change in the diameter of the powder chamber. Curve F is the average enlargement obtained from the measurements of 49 howitzers of the Model 1918 selected at random and a study of this will disclose that the increase starts at the origin of rifling and gradually grows greater towards the muzzle with slight changes in slope taking place at those points where the factor of safety changes appreciably. We are therefore forced to assume that this enlargement is due to some radial pressure other than the powder pressure but accumulative upon it and the analysis to be explained later is an effort to isolate these additional pressures and to calculate their probable values.

The form of the rifling groove in this howitzer is shown by the figure in the left hand corner of the set of curves and it will be noted that the driving and non-driving sides of the lands are made up of two curves of .03 inch and .09 inch radii respectively tangent to each other and to the top of the lands and the bottom of the grooves. A normal to the driving side of the land makes an angle of approximately 60 degrees with the bore of the gun and so any effort necessary to rotate the shell while passing through the howitzer would exert a pressure on all of the lands equal to the tangential effort divided by the cosine of 60 degrees; from this there results a total radial pressure between the rotating band and the driving side of the land of an amount equal to the total tangential force multiplied by the tangent of 60 degrees. It will be seen from this that any lands having a driving side of a shape other than radial will always exert an outward pressure upon the bore of the gun and acting in the same direction as the powder pressure.

There has been calculated by a rational formula, which is omitted here for the sake of brevity, the effort to rotate the 240 mm. proof slugs when fired at the velocity shown by the Curve A. This has a maximum value of 157,000 pounds at a point about 100 inches from the breech face but due to the fact that the twist of this howitzer increases until near the muzzle end this value does not drop below 135,000 except at that portion near the muzzle as shown by the curves. These values when multiplied by the tangent of 60 degrees for the reason previously explained and divided by the outside area of the copper band gives the minimum radial results that would be obtained and when added to the powder pressure curve B give a resultant radial pressure as shown by the curve C.

The curve C is at all points within the tangential resistance curve E and therefore could not cause the enlargements as shown by curve F. The factor of safety of these two curves are represented by the curve G and it will be noted that the numerical value of the several points drop appreciably from the breech end towards the muzzle except that portion which is reinforced by the muzzle swell. While these reductions show a marked change in the factor of safety along the bore of the howitzer, it still does not explain the enlargement for no permanent set can take place until the metal has been stressed beyond its elastic limit and it follows that this point is not reached until the factor of safety as used in gun design has become less than unity.

Tests conducted at the Watertown Arsenal and reported in the *Tests of Metals*, 1914, give the total effort required to force projectiles through a 12-inch mortar of the Model 1912. This mortar has the same shaped groove and the same method of twist as used in the 240 mm. howitzer and while the effort, previously referred to, is used up for a portion of the travel in engraving the band and in cold working the copper there



Left: 155 G. P. F. Gun Carriage Equipped with Caterpillar Adapters

Right: 8-Inch Howitzer Carriage Equipped with Caterpillar Adapters

is a length near the muzzle of about 34 inches long where the rifling is uniform and of constant cross section and as no changes are taking place in the shape of the copper when passing through this 34-inch section we are forced to assume that all of the effort required is that used to overcome frictional resistance between the rotating band and the gun tube.

When using a band of the same width and the same general characteristics as that of the 240 mm. howitzer it was found that a force of 495,000 pounds was required to overcome the resistance of the shell in this 34-inch length. The well-known relation between frictional resistance and load shows that there must exist a radial pressure between interior surface of the gun and that portion of the copper rotating band in contact with the gun of an amount equal to 495,000 pounds when the co-efficient of friction is assumed as 1. This value is taken delibrately high because any lower value merely means a greater radial pressure. The area of contact between the band and the gun bore of the 12-inch mortar is about 73½ square inches, therefore the unit pressure between the two surfaces is 6700 pounds per square inch. Assuming this unit pressure to be the same for the 240 mm. howitzer, its value is accumulative on that previously calculated for the tangential pressure. It is therefore added to curve C and is shown by curve D. It will be noted that this latter curve is at all points above the tangential resistance curve and, if our assumptions are reasonably correct, it explains the enlargements as shown by curve F.

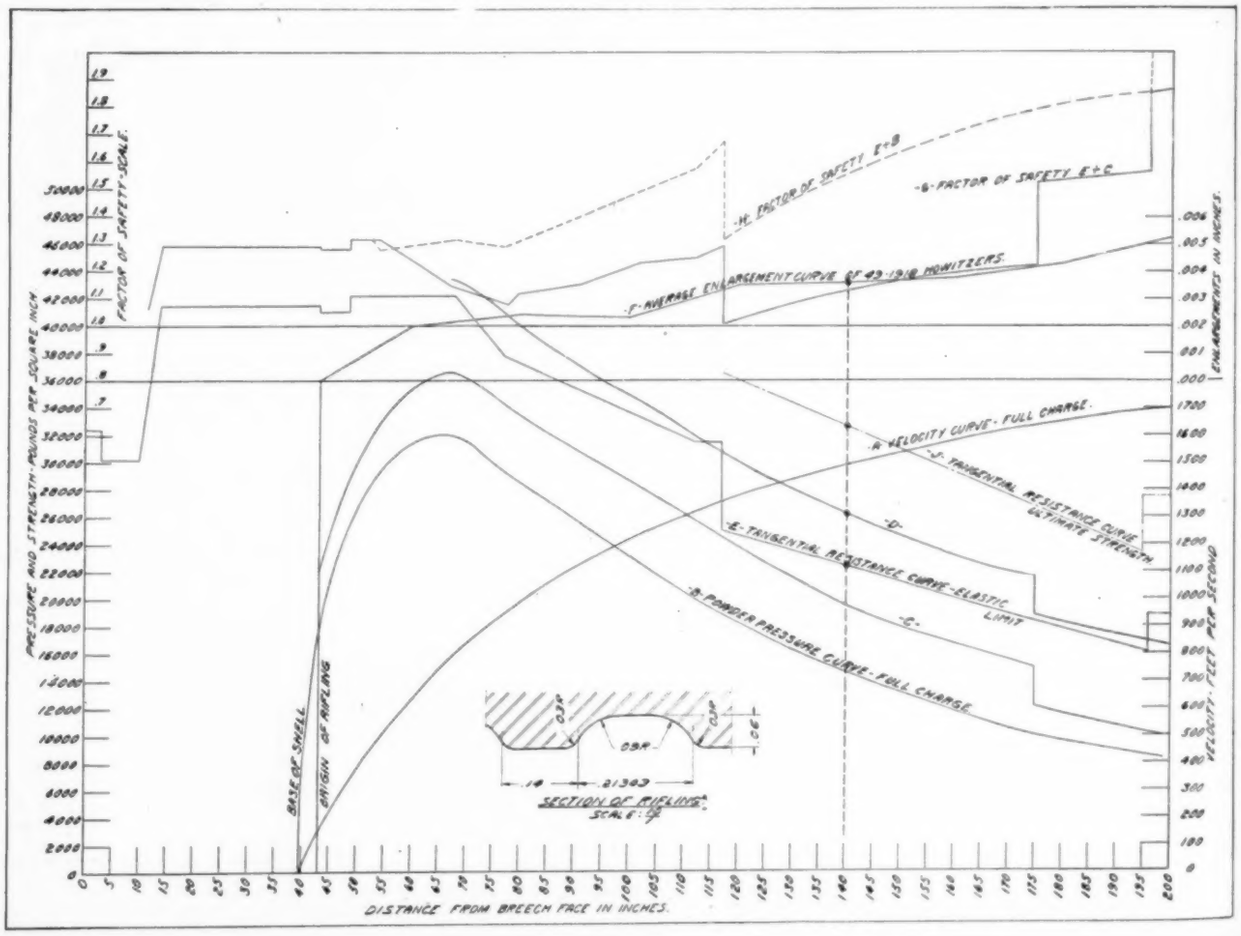
In order to check roughly this assumption a place where the howitzer tube is of one thickness and therefore not affected by shrinkage is selected at a point 140 inches from the breech. This point is so situated that the metal could not be constrained by the muzzle bell or by the jacket.

It will be seen from curve E that a radial pressure equal to 22,400 pounds per square inch, in the point in question would stress the metal on the interior surface of the bore of the howitzer to the elastic limit of 65,000 pounds per square inch which is that specified for the tube. The pressure taken at this point from curve D is 26,200 pounds, and without changing the cross section of the howitzer it would be necessary to increase the elastic limit of the metal to 76,000 pounds in order that no permanent set would result from an interior pressure of this amount. This is a proportional relationship and attention is particularly invited to the fact that the elastic limit should be increased 11,000 pounds per square inch.

Young's modulus for steel is practically 30,000,000 and while it only applies up to the elastic limit it is customary to consider that the same relationship holds true beyond the elastic limit for a reasonable distance. The average enlargement in the diameter at the 140-inch point is .0036 inch with a corresponding enlargement in circumference of .0117 inch. The entire interior circumference of the howitzer is equal to 29.7 inches, therefore, the unit permanent set per inch of circumference on the interior surface is equal to .00038 inch.

This permanent deformation when multiplied by Young's modulus shows that a unit stress of 11,400 pounds above the elastic limit would have to be applied, which checks remarkably close to the 11,000 previously calculated from the tangential resistance curve.

The Watertown tests used in the calculations of the last radial pressures are open to question because of the fact that the velocities were extremely low when compared to the actual velocity of a shell passing through a gun. The average of two tests for the entire length of bore is given as 500,000 pounds, which is that required to engrave the band, to cold work the copper and to overcome frictional resistance. The travel of the projectile was 153.7 inches, therefore, the total work was equal to 6,410,000 foot pounds. The total energy given up by a powder charge to a projectile consists of the energy of translation, the energy of rotation and the passive resistance of the shell through the bore of the gun. The energy of translation and rotation of the 12-inch mortar Model 1912 when firing a 700 pound projectile at 1800 feet per second is equal to 35,727,000 foot pounds. The Ordnance Department of the Army assumes that the passive resistance is equal to 12 per cent of the total imparted energy while the Ordnance Bureau of the Navy Department assumes 16 per cent. Due to marked effect upon friction by the surface of the bore of the gun either of these values are reasonably cor

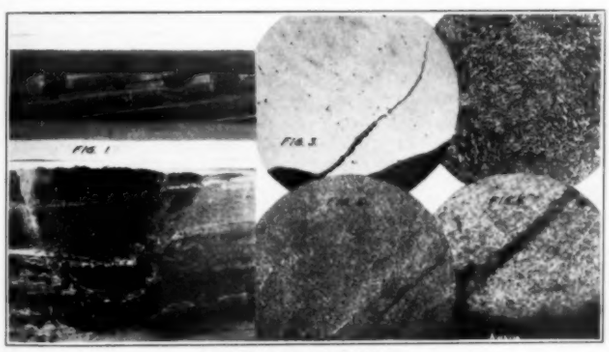

PRESSURE AND STRENGTH-POUNDS PER SQUARE INCH
FACTOR OF SAFETY-SCALE.
ENLARGEMENTS IN INCHES.
VELOCITY-FEET PER SECOND
DISTANCE FROM BREECH FACE IN INCHES.
H. FACTOR OF SAFETY E÷B
G. FACTOR OF SAFETY E÷C
F. AVERAGE ENLARGEMENT CURVE OF 43 1918 HOWITZERS.
A. VELOCITY CURVE-FULL CHARGE.
J. TANGENTIAL RESISTANCE CURVE ULTIMATE STRENGTH
D.
E. TANGENTIAL RESISTANCE CURVE-ELASTIC LIMIT
C.
B. POWDER PRESSURE CURVE-FULL CHARGE
BASE OF SHELL
ORIGIN OF RIFLING
SECTION OF RIFLING.
SCALE 1:1

rect. Assuming a mean of 14 per cent we then have 35,727,000 foot pounds is equal to 86 per cent of the total energy given up by the powder gas to the shell and 14 per cent of the total is equal to 5,810,000 foot pounds, which is a reasonably close check with the 6,410,000 foot pounds previously calculated when it is realized that the Watertown tests show a variation of 20 per cent of the passive resistance due to different conditions of the bore. Therefore, it seems that the theoretical conception of friction in that it is not affected by velocity is reasonably correct when considering the passive resistance of projectiles.

While it is realized that certain assumptions have been made in the previous discussion which are open to question, every effort has been made to make these assumptions extremely conservative and it is believed that the deduction is a logical explanation of the unfortunate enlargement of such a large number of howitzers. The 155 howitzer (Schneider design) and the 155 mm. G.P.F. guns have factors of safety only slightly greater than the 240 mm. howitzer, yet no trouble has been experienced with either of these weapons due to enlargement which is explained, however, by the fact that each has uniform twist which reduces very materially the tangential effort to rotate the shell and also the width of the copper rotating band is very small when compared to the 240 howitzer band.

Pastilles of 75 mm. guns.—The accompanying illustrations show the effect upon the metal of a gun tube immediately beneath those imperfections, known as "pastilles," which developed in 75 mm. guns during the war.

Pastilles are generally circular in shape, about ½ inch in diameter and up to .05 inch depth, always located with very few exceptions on the lower surface of the bore and at a point 2 or 3 calibers in front of the nose of the projectile when seated. It has been thought that the cause of these



Pastilles in 75-mm. Guns

imperfections is due to either the pressing down into the metal, by the passage of the shell, of a small globule of the tin lead alloy used for decoppering or the detonation of a partially burned sliver of powder from a previous round. The consensus of opinion seems to be that the latter reason is the true one and this is partially borne out by accompanying illustrations.

Figure 1 shows a section of the gun containing 3 pastilles.

Figure 2 shows the middle pastille magnified eight times.

Figure 3 shows a cross section at the bottom of the central pastille, unetched and magnified 100 times. The radial crack is very pronounced.

Figure 4 is an etched section of the metal near the pastille magnified 500 times. It will be noted that the crystalline structure of the metal has not been changed as might have been caused by cold working which would have resulted by the pressing in of the tin lead alloy.

Figure 5 shows the same cross section as figure 3 except that it is etched by a 4 per cent nitric acid alcohol solution while Figure 6 shows the same magnified 500 times.

It will be seen that in neither of the latter two pictures has the metal changed appreciably in its crystalline structure and the radial cracks which appear must have been caused by some very violent blow such as would have been delivered by the detonation of a sliver of unburnt powder.

Test on the formation of pastilles is now being conducted by the Ordnance Department and additional information will be furnished in the near future.

Rock Island Arsenal Notes

Manufacture of 1100-pound Demolition Bomb, Mark III.—The 1100-pound demolition bombs, Mark III, used to sink the ex-German battleship *Ostfriesland*, were manufactured at the Rock Island Arsenal.

Figure I shows the bomb assembled and gives the nomenclature of the components for the bomb. The front body is a steel casting with a tapped hole in the nose and a finished space at the rear on which the front of the middle body fits. This forms a lap joint when welded. A suspension lug is secured to the front body by four rivets. The front body is tested under a hydraulic pressure of 100 pounds per square inch, in order to discover any blow holes in the casting or

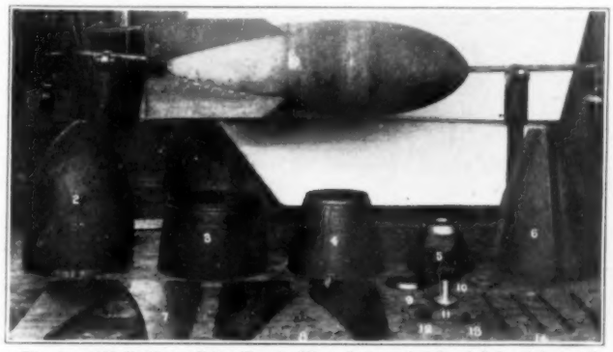


Fig. 1. 1100-lb. Demolition Bomb, Manufactured at Rock Island Arsenal

1. Assembled Bomb
2. Body Front
3. Body Middle
4. Body Intermediate
5. Body Rear
6. Cone Sector
7. Fin
8. Suspension Lug
9. Rear Bushing
10. Reducer
11. Fin Coupling
12. Shipping Plug Nose
13. Shipping Plug Rear
14. Fin Brace

other defects in the metal. The weight of these castings varies from 272 pounds, minimum, to 302 pounds, maximum. This variation in weight does not affect the center of gravity to any extent, since the established center of gravity is 20 inches from the front end, the actual tests show a variation of ¾ inch on either side of the established center of gravity.

The middle, intermediate and rear bodies are formed of sheet steel. The first drawing dies completed were for the middle body and were designed for a double acting hydraulic press, which was rated for 450-ton pressure on the plate and 150-ton on the center ram. This being the largest double acting hydraulic press available at the Arsenal. This machine proved inadequate for the purpose. By using an 1800-ton single acting press, the pressure required on the center ram was found to be 318-ton. Steps were immediately taken to convert a single acting 1500-ton press into a double acting machine. In the meantime, as soon as the dies for the sections were completed, the sheet steel section for 60 bombs were finished in the single acting press.

In manufacturing the suspension lugs several blanks were machined to the required shape and formed in a die. It developed that the forming operation reduced the thickness of the stock .015 inch in the point of the loop. This being too much of a reduction it was decided to form the lug of stock the full width of the lug and to mill the loop to the required width after forming. Test specimens prepared by this method show a reduction of .005 inch in the section.

The specifications state that the welds joining the sections of the bomb shall have a tensile strength of at least 75 per cent of the tensile strength of the metal joined. Tests of the welding showed the strength of the weld to be 90 per cent of the strength of the original material.

When welding the rear bushings to the rear body it developed that the bushings were distorted due to the welding so that they had to be retapped. In future work the bushings will not be tapped until after the welding operations.

Two methods of forming the cone sector were tried. The one adopted consisted of heating the blank and forming it with a drop hammer allowing the piece to cool between the dies. These cone sectors were fitted on a conical shaped arbor and the excess material on each end of the sector was removed in a lathe. By this method four sectors were finished at a time but this operation, while producing a satisfactory cone proved to be too expensive. It is proposed for future work to trim the small end of the sector in a punch press die and the large end in a circular shear.

Figure 11 shows the successive operations of drawing the middle body.

An air pressure test of 30 pounds per square inch was applied to the completed bomb, before the outside was painted, to test the welding of the joints. This test showed that the riveting of the suspension lug to the front and middle bodies was not air tight. This defect was overcome by drilling the hole for the rivets the same diameter as the rivets and coating the rivets with red lead before driving. Hot riveting was tried for the suspension lugs but the results were not satisfactory due to the leakage of air at pressure test.

Preservation of Rubber Tires.—The adoption of solid rubber tires for artillery vehicles, resulting in the purchase of a considerable number of tires mounted on base bands by the Ordnance Department, confronts that Department with the question of how to prevent the deterioration of such tires in storage. It is generally recognized that sunlight has a deleterious effect upon rubber and consequently tires stored at Rock Island Arsenal, where there are several thousand, are placed in light-tight storehouses with concrete floors under as nearly ideal conditions as possible. However, field storehouses are not light-tight and a test is being run at the arsenal in which the aging of twelve tires painted with an approved aluminum paint is being compared with that of twelve similar tires not painted. The paint used is from the following formula:

50 parts of shellac by weight
26 parts of borax by weight
168 parts of water by weight
32 parts of alcohol by weight

To 30 parts of this, well mixed, add 5 parts of aluminum bronze by weight.

Upon starting this test the engineer in charge was somewhat at a loss for a proper test of the rubber, since commercial firms admittedly design solid tires with a view to long mileage rather than ability to stand storage. They have not even developed a standard penetration or resiliency test for perfectly fresh rubber. It was first decided to depend principally on scleroscope readings; later a Whitney rebound instrument was acquired and the reports now show readings from both instruments. Temperature is found to affect the scleroscope results more than was anticipated. In July 1921 (see table below) the temperature of the air in the vicinity of the tires was 75 degrees F.

In setting the test, some of the tires were weighted. A painted tire and an unpainted tire of the same make were set side by side and 20 inches apart and pig iron piled inside to the weight which would fall upon those tires were they assembled to a vehicle. Others were stacked—that is, piled one on another—in horizontal position. Three different places were marked on each tire with paint (in the case of weighted tires one of these points being directly under the weight), and at these points observations are taken each six months with micrometers, measuring from the outside of tire to inside of base band, with a scleroscope having a "regular" diamond point hammer, and with a Whitney rebound instrument. The scleroscope is supported vertically by the hand of the operator above the point where the temperature of the hand might effect the action of the hammer and is applied within one-half inch of the center line of the tire. Several trials at each point are taken, and the readings (which vary 8 to 10 points) are averaged. No difference in scleroscope readings which could be caused by the layer of paint has been noticed.

The test having been run a year and a half on tires made in 1918, certain of the tires are already beginning to show a hardening change indicated by the scleroscope and confirmed by the more or less crude test which is accomplished with the point of a pen knife, the experience of the operator enabling him to judge in some degree of the resilient character of the rubber. While most of the tires are still in very fair condition, it is observed that the painted tires are generally not quite so hard as the unpainted, indicating some small virtue in the painting. Incidentally it is observed that two sample tires received at the arsenal in 1913 are still very soft and resilient and appear to be in no way affected by the length of storage.

The following table averages the readings at the second and third stations for all the tires of the same make, the points under weight not being considered:

Maker	*Scleroscope readings averaged.*		
	July, 1920	Dec., 1920	July, 1921
A—Painted	49.4	29.4	53.1
Not painted	48.5	27.	53.7
B—Painted	55.2	30.7	55.6
Not painted	60.2	36.7	56.2
C—Painted	46.9	30.6	51.
Not painted	46.	34.9	52.5
D—Painted	59.3	48.3	52.4
Not painted	57.3	46.9	55.2
E—Painted	51.4	40.2	52.7
Not painted	53.7	35.2	53.5
The two 1913 tires not painted		46.	66.3
		40.5	59.

Velocimeter.—It is necessary to obtain, and record, the velocity with which each recoil mechanism returns the gun into battery. This data is used as a check upon the functioning of the mechanism and provides information upon which the design of counter-recoil buffers on similar materiel is based.

Heretofore the velocity has been obtained from a graph scratched on a smoked steel ribbon by a vibrating needle secured to the gun carriage. A pin on the bracket which holds the ribbon starts the needle vibrating. The ribbon brackets were made new for each gun due to the different diameters of the gun.

A velocimeter has been designed by Mr. W. C. Palmer, mechanical draftsman, which records the graph on a strip of paper so that it may be retained. The accompanying illustration shows the instrument set and with a paper strip in place.

Comparing this instrument with the former one proves it to be less expensive, saving in both time and material. The instrument can be used with any gun which has a recoil not over 72 inches.

The lower drum (B) has wound upon it the cable (A) which is fastened to a recoiling part. In the base of this drum is a spiral coil spring having one end fastened to the drum and the other end fastened to the pivot. When the cable (A) is pulled to the rear by the recoil of the gun the drum is rotated and the spring wound up. This spring rotates the drum as the gun returns into battery. The drum is controlled by the cable attached to the gun.

Fastened on the bottom of the upper drum (C) is a pawl which works in teeth cut on the lower drum hub. This pawl runs free as the cable is unwound but when the drum moves in the opposite direction the pawl picks up the upper drum and causes it to rotate with the lower drum. The upper drum has one end of a strip of paper fastened to it and in rotating moves the paper under the pencil in the barrel (D). A spindle (E) is provided to hold the strip of paper.

When the upper drum starts to rotate a trip (F), fastened to the bottom of the drum, pushes the lug of the plunger (G) from its notch and allows the plunger to fall. The vibrator which has been supported by the plunger is set in motion, and by means of the plunger pencil records its beats upon the moving strip of paper.

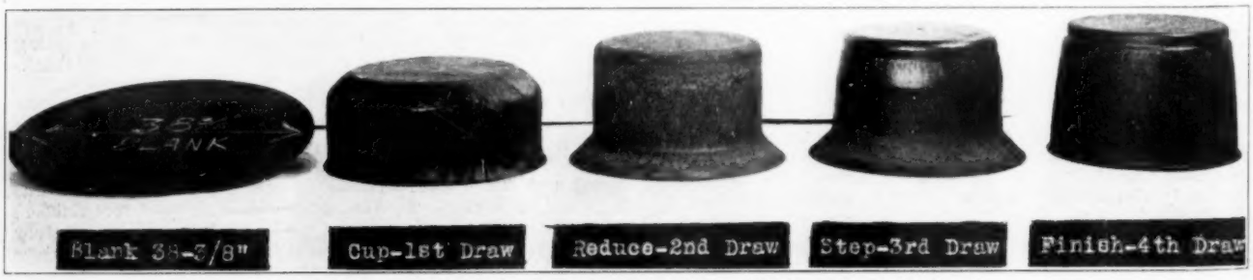
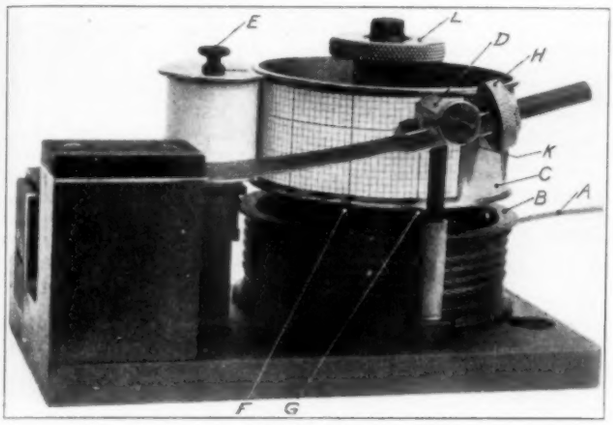


Fig. 2. Sequence of Operations in Forming Middle Body—1100 Pound Demolition Bomb

By moving the nut (H) the period of vibration of the vibrating spring can be changed. A spring in the barrel of the pencil holder causes the pencil to bear on the paper. The pressure of the pencil may be varied by the nut (K). The large nut (L) above the upper drum is for adjusting the location of the trip in relation to the plunger lug and disengages the upper drum from the ratchet mechanism.

Before using the velocimeter a base line is drawn upon the paper ribbon showing the vibrator arm in its still position. On this base line measurements are taken from one wave to



Velocimeter

the next. These measurements give the space function (S) of the formula $V = \frac{28.}{T}$ The vibrator having been calibrated so that the beats per second are known, furnishes the time function (T). These two values known, it is a simple mathematical calculation to obtain the velocities (V) which vary from zero to maximum and back to zero. The velocities plotted against the length of recoil show the velocity at each point of the counter recoil.

Watertown Arsenal Notes

Some Results from a Recent Investigation of Poisson's Ratio.—While making some tests for this Arsenal to determine the cubical compressibility of a number of samples of steel, Professor Bridgman incidentally investigated the constancy of Poisson's Ratio, and, since there have been recent discussions in ARMY ORDNANCE regarding this elastic property, it would perhaps be interesting to a number of the readers to learn of the results obtained.

Poisson's Ratio, it will be recalled, is the ratio of the lateral contraction to the longitudinal extension of a bar when acted upon by a force parallel to its length and any knowledge regarding this elastic property is valuable indeed, particularly so in gun construction.

Experiments were performed on six solid steel bars 18 inches long and 1.000 inch diameter between grips. The load was applied by means of a Sellers Hydraulic machine, the specimen being in a horizontal position. The measurements of the changing length and diameter were carefully made by the use of extensometers of the deflecting mirror type, the deflections being observed by means of a telescope and scale. The set up is shown by the accompanying photo.

The six bars were of different grades of steel as shown by the following table of chemical compositions.

Bar	C.	Mn.	Si.	S.	P.	Ni.	Cr.
1	.495	.61	.13	.018	.013	Trace	.07
2	.495	.61	.13	.018	.013	Trace	.07
3	.36	.68	.195	.024	.046	3.38	.23
4	.36	.68	.195	.024	.046	3.38	.23
5	1.08	.23	.14	.021	.020	Trace	.05
6	1.08	.23	.14	.021	.020	Trace	.05

The observations were made on these bars after annealing and machining with the following results:

Bar	*Poisson's Ratio*
1	.356
2	.519
5	.429
6	.284
3	.593
4	.257

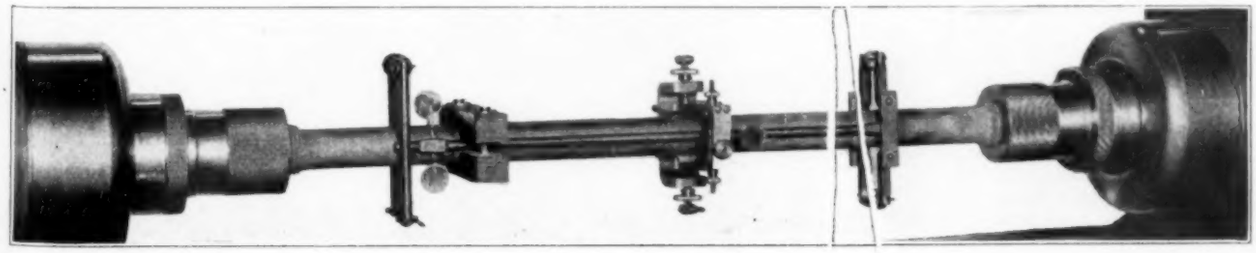
One is immediately struck by the great divergence of results, and this was found to be caused by the presence of permanent internal strains that, due to the length of the specimens, were introduced during the machining. It was noticed also that, due to these internal strains, there was a great deal of hysteresis or sluggishness on the diameter in response to the changing tension. It was, therefore, found to be necessary to reanneal the bars and repeat the experiment in order to obtain any satisfactory values of Poisson's ratio.

The reannealing was performed in an electric furnace, the specimens heated to 800° C. after which they were slowly cooled in the furnace for three hours. During both the heating and cooling, the specimens were maintained in a vertical position. That this treatment was most effective is shown by the fact that the hysteresis almost entirely disappeared and the Poisson's Ratios again obtained by direct observations came much closer to agreement. They were as follows:

Bar	*Poisson's Ratio*
1	.335
2	.342
5	.349
6	.342
3	.332
4	.331

One peculiar and interesting fact was brought out in these experiments and that was the greater sensitiveness of the diameter measurements to hysteresis as compared to the longitudinal measurements. This would hardly be expected because the changes of the diameter are very much less than the changes of the length. This sensitiveness is plainly shown in Table No. 1 where it is noticed that the Poisson ratio varies from .519 maximum to .257 minimum.

As a comparison between the sensitiveness of the diameter to internal strains and the comparative insensitiveness of the length to the same trouble, it is interesting to note that in bar 3, for instance, annealing changed Poisson's ratio from .593 to .332, while under the same conditions Young's Modulus changed only from 2.83×107 to 2.81×107.


View Showing Specimen in Machine with Instruments in Place

It was most strongly emphasized by Professor Bridgman that not a single measurement in the entire experiment furnishes the slightest evidence that there is the smallest deviation from the linear relation between stress and strain even at the smallest stresses, but on the contrary the evidence is positive and convincing that the linear relation holds over the entire range of stress.

Mention has been made of the measuring devices of the deflecting mirror type. The photograph giving two views of the one actually used in these experiments shows very clearly its nature. This Expansometer as it was called was designed at the Arsenal Laboratory from rough sketches submitted by Professor Bridgman, and it will be noticed that it is an adaptation from Martens.

For those unfamiliar with the working of this type of instrument it may be said that the specimen "A" is gripped by the points "B," and the thumb screws "C" are tightened down till the jaws are parallel. The balancing is taken care of by the movable nuts "D," while any lack of parallelism in the jaws is finally adjusted by manipulating the little thumb screws "E" that control the spring tension. As the diameter changes, the jaws open or close in a vertical plane, pivoting about the points in the thumb screws "C." This opening or closing causes the bent portion of the jaws to slide by one another and in the space between the two, resting on the one side on a hardened steel plug grooved to receive it, and on the other side resting flat against a vertical spring, is a lozenge shaped spindle "F" that is rocked back and forth by the movement of the jaws. This spindle projects through the jaws far enough to provide room to fasten a galvanometer mirror "G" to it, and it is the movement of this mirror, as indicated by a beam of light, that is observed through a telescope.

In this particular instrument the points were so arranged that there was an internal multiplication of movement in the ratio of five to one while as actually set up and used, due to the telescope and scale, there was a magnification of about 3500.

Twenty-Year Club, Watertown Arsenal.—In February, 1920, the 20-Year Club at the Watertown Arsenal was organized. All those who have been employed in the Ordnance Department of the United States Army for a period of twenty years or more, and who are employed at the Watertown Arsenal are eligible for membership.

The Club took for its motto, "Loyalty, Co-operation and Welfare of our Government." Its object is to gather together those of the employees of the Watertown Arsenal who have had twenty years' service or more; to promote good fellowship; to meet occasionally and talk over old times; and to promote the efficiency and welfare of the Watertown Arsenal and the members of the organization.

In order that the commissioned officers on duty at the Watertown Arsenal would be conversant with the discussions and problems taken up by the 20-Year Club, these were made honorary members and thereby have permission to frequent the meetings and other functions and take part in the discussions.

The Club also made a rule that all pensioned members should become honorary members of the Club, but these as well as commissioned officers would have no vote.

In order to take care of the interests of the Club, four principal standing committees are appointed as follows:

The Internal Affairs Committee,
The External Affairs Committee,
The Advisory Committee,
The Entertainment Committee.

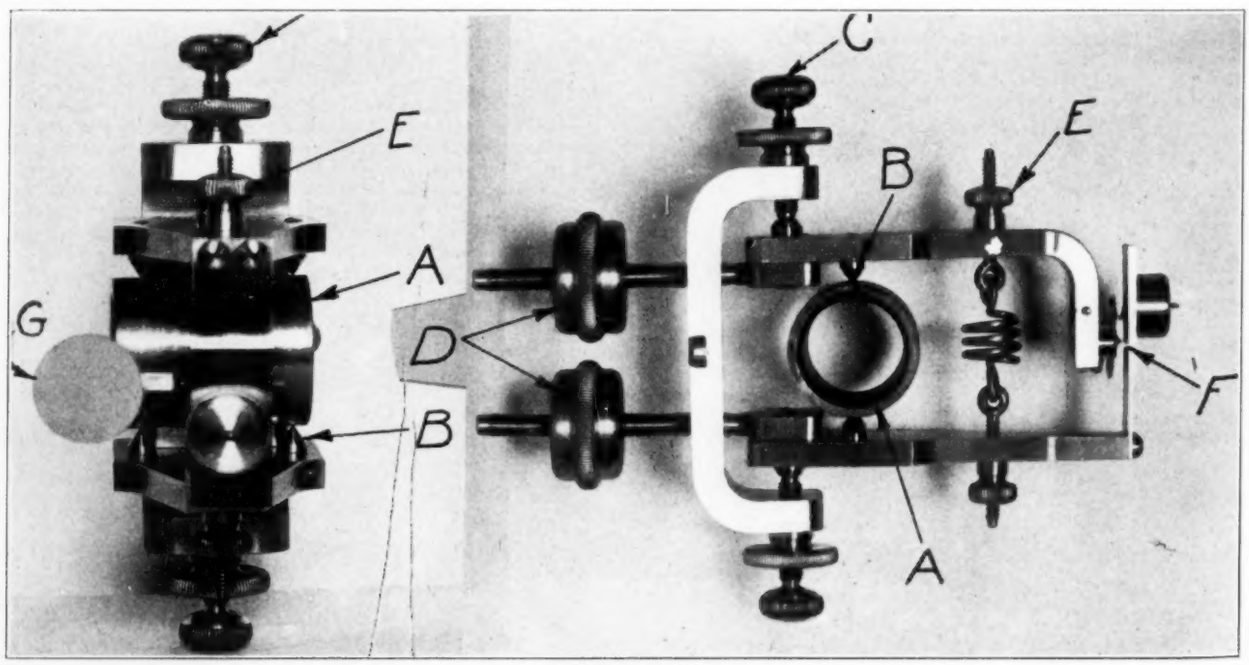
Since its conception, the Club has been very prosperous and at the present time has sixty-eight members. Since the Retirement Act went into place, ten of the members have been pensioned. Within the next two years, there are fifteen employees at this Arsenal which will become eligible for membership in the 20-Year Club.

Of the present members of the Club, there are a number who have been employed at the Watertown Arsenal for a considerable length of time beyond the twenty years, and the oldest employee in the length of service is Mr. Edward F. Burke who entered the Government service at the Arsenal on July 12, 1880, and has therefore been serving the Government for 41 years.

In this time he was employed as machinist and subsequently was promoted to assistant foreman, foreman, and in charge of the Planning Room of the Seacoast Shops. Recently he was transferred to the Engineering Division where he is acting in liaison between the Engineering Division and the various manufacturing shops for the purpose of bringing the Engineering Division and the manufacturing divisions in close co-operation. He has charge of the distribution of drawings, as well as elucidation of same when any question is brought up by the foremen or superintendents of shops.

There are several other employees at the Arsenal who have been engaged for more than 30 years and are still active in the duties assigned to them.

It may be stated in conclusion that the Commanding Officer of the Arsenal, General T. C. Dickson, is taking great interest in this Club and that he relies on its members to assist him in problems which are of interest to the Government as well as to the members of the Club.



The Expansometer

Watervliet Arsenal Notes

Conversion of 5-inch Gun into 3.3-inch Long Range Gun.—Watervliet Arsenal recently converted a number of 5-inch Model 1897, 45-caliber guns to 3.3-inch 68-caliber guns. One of the first difficulties to be overcome in converting the 5-inch guns to 3.3-inch guns was to find a method which would give satisfactory results in assembling the liner. The great thickness of the liner at the muzzle end as compared with the cross section of the gun at the same point made it questionable as to whether or not it would be possible to hold the liner on the shoulder without the application of an exterior force of some sort. It was considered worth while to attempt to assemble the liner by dropping it into the heated gun without removing the gun from the furnace; allowing the breech end of the liner to expand as rapidly as possible in order to hold the liner in contact at the shoulder; the muzzle end of the liner being kept cool by circulating water through the liner from the muzzle end to a point within 8 inches of the contact shoulder.

The gun was heated to a temperature of 600 degrees F. which provided an assembly clearance of .019 inch at the muzzle end. A clearance of only .005 inch was maintained at the breech end; the extreme breech end of the liner being expanded .017 inch by the application of four (4) small gasoline torches immediately before assembly. The exterior of the liner from the muzzle end to a point within 8 inches of the contact shoulder was coated with a mixture of powdered graphite and light machine oil which was rubbed down very thin. The liner was then assembled in the gun and water circulated through it for two (2) hours; the heat being maintained in that part of the furnace corresponding to a length of 120 inches from the muzzle of the gun. Heat was applied to this section of the gun in order to supply heat to the smaller cross section of the gun thereby maintaining a difference of temperature between the gun and liner preventing contact between liner and gun until such time as the breech end of the liner at and to the rear of the shoulder was securely gripped.

When the gun with the assembled liner was removed from the furnace it was found that we were unsuccessful in holding the liner on the shoulder; measurements showing that it was .225 inch off shoulder. The result being unsatisfactory a change in the method of assembly was necessary. The method described below was then followed. It was determined that we should heat the gun in the furnace, breech end up, to 650 degrees F. first providing the gun with a heat retainer over the muzzle section. An ordinary soil pipe was used for this purpose. The space between the gun and the interior walls of the pipe was filled with a coarse building sand. The liner was provided with water inlets in the breech end lifting plug and with steam outlets in the muzzle plug; both plugs being screwed into the liner. Two pipes were brought off from the steam outlets at right angles to the long axis of the gun a sufficient height to permit the interior of the liner being filled with water before overflow would occur. The liner was then coated with a mixture of oil and graphite the same as explained in the previous operation and lowered into the gun in the furnace; the gun being at a temperature of 650 degrees F. The cover was then put back on the furnace and heat maintained for a period of three (3) hours. Gun and liner were then removed from the furnace and placed in a one thousand (1000) ton horizontal type hydraulic press. It was necessary to perform the transfer of the gun from the furnace to the hydraulic press in the quickest possible time in order to eliminate any considerable drop in temperature due to radiation. Therefore all preparations to the minutest details were made beforehand.

As soon as the gun was seated in the hydraulic press the two (2) water inlets were provided with hose and a 55 pound head of water applied simultaneously with a pressure of 30 tons on the breech end of the liner. It was determined that water should be applied for an interval of one minute which time should be sufficient to reduce the temperature of the liner sufficiently to break contact with the gun. Therefore after water had been applied for one minute the pressure on the hydraulic press was raised gradually to 305 tons, 20 seconds being taken for the increase in pressure from 30 to 305 tons. Ten seconds after this pressure was first obtained the liner had moved forward onto the contact shoulder, or in other words, the liner was in contact on the shoulder one and one-half minutes after the application of water and pressure. As soon as the liner was seated water circulation was discontinued, the liner drained and allowed to assume the temperature of the gun. At the same time the pressure in the hydraulic press was reduced to 150 tons and held at that value for 45 minutes after the gun was removed from the press and allowed to cool.

Measurements taken after cooling showed the liner to be hard on shoulder .017 inch. The liners in the other guns were successfully assembled by this method. The first gun assembled which was unsuccessful was also treated in the same manner with entirely satisfactory results.

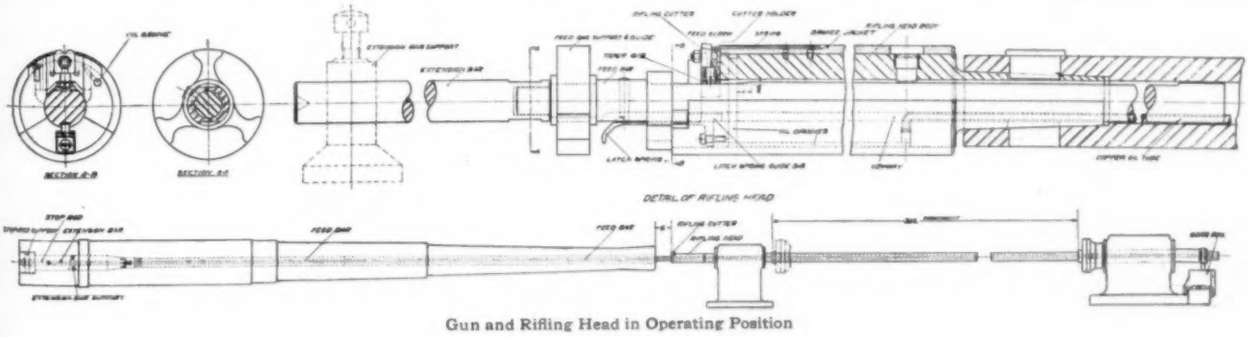
The average changes in length of the liner and gun were as follows:

Change in length of gun	plus .008 inch
Change in length of liner	minus .006 inch
Amount on shoulder	plus .009 inch

In order to prevent interference in the seating of the projectile an unusual form of powder chamber was called for in that the 3.42-inch diameter zone directly in the rear of the rifling had to be bored .01 inch eccentric (as shown in Fig. 2) with the remainder of the powder chamber and the bore proper. This zone was first machined concentric with the remainder of the bore to 3.40 inches diameter using standard reamers. An eccentric cut was then taken enlarging this zone to 3.22 inches with the special fixture shown in view 3. The construction of the special fixture is shown in sufficient detail in views 3 and 4 to require no further explanation. By use of this fixture no difficulties were encountered in finishing the bore smooth and accurately to the dimensions specified. The pick-up of the beveled surface joining the 3.3 inch diameter bore with the 3.42-inch diameter bore being in perfect alignment.

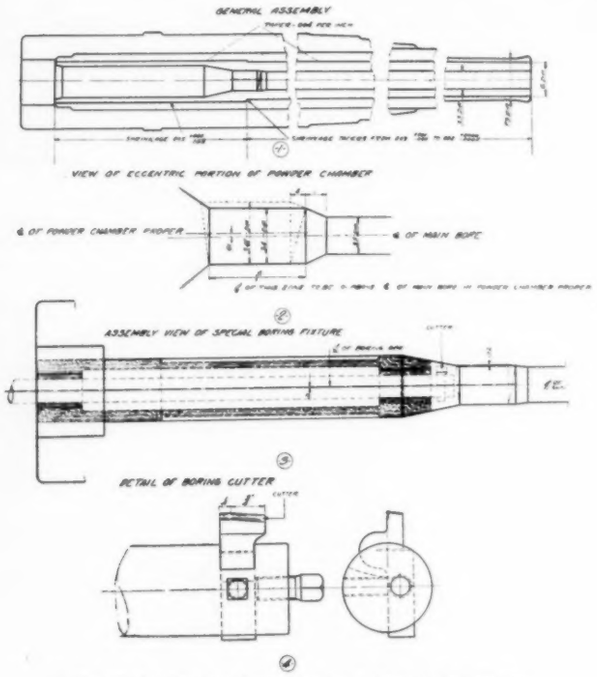
One of these guns specified a unique type of rifling in that the grooves were of a continuous taper starting at a depth of .03 inches at the origin of the rifling and tapering to a zero depth at a point 18 inches from the muzzle end of the gun. That part of the bore 18 inches from the muzzle end being a smooth bore the same diameter as across the lands of the rifled portion. The type of rifling used is what is known as the hook type being a uniform right hand twist with a width of grooves of approximately .22 inch; width of land .1 inch; depth of grooves .03 inch. The rifling of this gun was accomplished by designing and constructing a special type of rifling head—description of which follows.

The body of the rifling head was prepared with a 1.25 inch diameter reamed hole throughout its length. Passing through this reamed hole was a feed bar made from mild tool steel which was turned and ground to a close sliding fit in the rifling head body being provided with one flat side the surface



Gun and Rifling Head in Operating Position

of which was tapered to correspond with the taper of the rifling grooves. The exterior of the rifling head was enclosed by a bronze jacket. Diametrically opposite the taper surface of the feed bar a keyway was cut the entire length. This keyway was used for the purpose of keeping the feed bar in proper alignment in the head as the head was rotated to give the proper rifling twist to the rifling grooves. This keyway also served the dual purpose of providing a recess into which a small copper tube was assembled; this tube being used to convey lubricating oil to the rifling cutters. The copper tube was secured at one end of the rifling head, the other end protruding into the oil chamber in the rear of the driving housing. A dovetailed recess was milled on one



5-Inch 45-Caliber Gun Converted to 3.3-Inch 68-Caliber Gun

side of the rifling head body which was provided with an adjustable slide or cutter holder which was used for carrying the rifling cutters.

The lower end of this slide was provided with a tapped hole into which was assembled the feed screw. Directly under the feed screw a short taper gib was provided which traveled on the taper surface of the feed bar projecting the rifling cutters as the rifling head moved along the feed bar. The rifling cutter holder was forcibly held in position against the tapered surface of the feed bar by means of a flat spring assembled flush with the outside surface of the bronze jacket, being secured at the end furthest from the rifling cutter holder. Diametrically opposite the rifling cutter holder an opening was provided for the assembly of a latch spring which is used to lock the feed bar and the rifling head body together on the return stroke. This latch spring being provided with a lug that keeps the feed bar and rifling head in alignment as stated in a previous paragraph.

The forward end of the feed bar is provided with an extension bar which in operation rests against a stop rod permanently assembled in the powder chamber. This extension bar passes through a support provided in the powder chamber and centralizes and supports the feed bar to which it is attached. The forward end of the feed bar is also provided with a three-legged bronze support turned so as to give a sliding fit in the bore of the gun. This bronze support being used to centralize and steady the feed bar when it is being pulled through the gun to starting position after the return of the head.

Before beginning the cutting operation the feed bar is pulled out of the rifling head body until the end of the extension bar rests against the stop bar in the powder chamber. With this position of the feed bar and with the slide pressed downward by the spring on the rifling cutter holder the gib rests on the deepest portion of the flattened taper surface on the feed bar. The rifling cutter holder is then adjusted to the desired depth of cut after which the head is permitted to travel into the gun; the rifling cutters cutting a tapered groove the same taper as the flat surface on the feed bar. The rifling cutter holder being fed out as it travels along the feed bar.

At the end of the stroke after the cutter has traveled approximately one-half inch past the origin of the rifling the gib begins to slide down a bevel .05 inch by .1 inch provided in front of the highest point on the flat surface of the bar. When the gib has reached a point about one-half inch forward of this bevel the rifling cutter is fully retracted and the latch spring has locked the feed bar to the rifling head body and the head is stopped by an automatic throwout provided on the rifling machine.

A clearance of .03 is provided between the bore diameter of the gun and the rifling cutters when the rifling cutter holder is in retracted position permitting the head to be withdrawn by reversing the rifling machine. After the rifling head with the feed bar has been withdrawn to starting position the latch spring is released by hand and the feed bar again pulled forward so that the extension rod comes in contact with the stop in the powder chamber and another cut started in the manner described above. Accurate rifling as called for by specifications was performed with the rifling fixture described. The time required for rifling was excessive from a production standpoint due to the fact that the head was manufactured with only one slide permitting the cutting of but two grooves at a time. If this type of rifling was to be performed on a production basis provision would be made to return the feed rod to starting position rapidly by power instead of by hand as the time consumed in performing this operation is considerable.

Frankford Arsenal Notes

Optical Plotting Board.—As a result of the test of the sample optical plotting board furnished Fort Monroe for test, the Coast Artillery Board has decided that certain features of it are valuable and it has recommended that a new board be constructed for further test. A number of changes recommended by the Coast Artillery Board will be incorporated in the new board and the size will be considerably reduced. The scale of the board will probably be 1,000 yards to the inch and it will be capable of plotting to ranges of 50,000 yards.

Spotting Instruments.—Orders have been received for the design and manufacture of two artillery spotting instruments for Coast Artillery and two similar instruments for Field Artillery, for test. These instruments will be designed for use by an airplane observer and will permit him to determine immediately and without any calculation, the distance of the fall of a shot from the target, as well as the mathematical bearing of the same relative to the target. This information will be sufficient to enable necessary corrections to be applied at the gun.

Airplane Observation Instrument.—An order has been received to design and manufacture an airplane observation instrument particularly adapted for field artillery target location. The usefulness of airplanes in locating targets for field artillery is now very much limited by the fact that no suitable instruments are available to enable the observer to locate the target accurately with respect to his own position. The proposed observation instrument will be so designed that the observer will be able to determine when he is on the line battery-target and at that instant to measure the angles subtended at the plane by the lines of sight from battery and target. The altitude of the plane being known, the battery will be able to observe on the plane and the data so obtained together with that determined by the observing instrument in the airplane will be sufficient to completely solve the problem of locating the target with respect to the battery.

Anti-aircraft Fire Control.—Tentative specifications have been prepared covering the design and manufacture of one complete anti-aircraft fire control unit of an entirely new type. It is intended that this computer shall be more automatic in action than any of the instruments heretofore employed, also that it shall control its guns by the indirect fire

method only. It is hoped that this instrument will eliminate a great deal of uncertainty and inaccuracy now existing in anti-aircraft fire control and that in the long run it will prove much more economical as a service instrument.

Optical Glass.—Experimental work is being conducted on a new method of uniting optical glass without the use of Canada Balsam or other cement. Sample prisms have been constructed by this method which apparently are satisfactory. If successful, this will enable complicated erecting systems to be constructed the components of which will be as rigidly and permanently united as though made of one piece. This is particularly advantageous for prism systems used in telescopic sights as it lessens the possibility of derangement due to recoil of the gun.

Observation Tower.—Work has been begun upon the reconstruction of an Observation Tower which was captured from the Germans during the World War. This tower is in reality a huge periscope adapted for use on land which enables an observer—standing on the ground—to view the entire horizon through an objective, elevated approximately 80 feet. The objective is carried by a telescoping tube which can be readily erected by means of a windlass carried at the base of the tower.

The tower is mounted on a two-wheeled carriage and when collapsed, the entire instrument resembles a 75 mm. field gun in size and general appearance. A two-wheeled limber which carries the optical accessories completes the equipment. Seats are provided for a crew of six men. Two of these towers were captured in the war, both of which were in fair mechanical condition, but the optical parts were either missing or broken. After the tower is completed, it will be sent to Fort Sill to be given a test in the field.

Loading Cycle for the Anti-aircraft Gun Mounts, Model 1920.—In the design of the new 3-inch and 4.7-inch A. A. mounts, Models of 1920, has been incorporated a special means for fuse setting and loading. This comprises a loading tray, a pneumatically operated ram and a fuse setter capable of a movement of reciprocation parallel to the axis of the bore of the gun upon tracks along the cradle frame. The rate of fire and weights of the projectiles for these guns require these refinements in fuse setting and loading in order to diminish that interval known as the gunner's time.

When the loading tray is thrown into the fuse setting position where it clears the gun, the round of ammunition is placed upon it. The fuse setter, having been given the announced setting by displacing those collars of the device which engage the pins of the fuse, is unlatched from its "off" position. A spring forces it upon the fuse of the projectile, whereupon a handwheel that drives both collars simultaneously is turned until it is stopped by the pin in the fuse body. The fuse has then been set to the same amount as the original displacement of the collars. When these operations have been completed the fuse setter is forced back to its "off" position where it becomes latched.

The one who operates the tray then throws it into loading position and trips a lever that opens a valve through which compressed air passes. One of the pistons to which the ram mechanism is fastened is forced forward to the extremity of its travel whereupon the air is passed into the second cylinder immediately picking up the ram and continuing its travel until the round has been loaded into the chamber of the gun. The tray is then thrown back to the fuse setting position and the gun fired.

Interlocks between the elements of the mechanisms have been provided so that it will be impossible to throw the tray from fuse setting to loading position before the fuse setter has returned to the "off" position. It will also be impossible to fire the gun until the tray is clear, that is, in the fuse setting position.

It is anticipated that this combined fuse setting pneumatic loading apparatus will reduce by at least one second the usual six-second gunner's time interval. Although the fuse setters for the pilot mounts will not be so provided, they can be interlinked with the sighting system, slightly modified, in order to permit of an automatic fuse setting.

Small Arms Division

Springfield Armory Notes

1921 *National Match Rifles.*—The manufacture of the Springfield 1921 National Match rifles will be completed in the near future. These rifles represent a sincere effort by all concerned to produce an accurate rifle. The following details covering its description, testing, etc., are of interest.

Description: The 1921 National Match Rifle is the United States Rifle, Model 1903, especially manufactured from steel billet to completed rifle according to very close dimensions that have been found by careful test and experience to give the best results, both for accuracy and ease of manipulation. The barrels are machined from special heat-treated steel known as Springfield Armory Class "A," and have stood tests at chamber pressure of 125,000 pounds per square inch. Barrels of this stock have been frequently fired 10,000 rounds before losing their accuracy. The barrel is rifled with double scrape cutters to insure a smooth uniform groove and to avoid pockets and ratchets. The rifling is uniform, right hand, one turn in ten inches. The minimum diameter of bore is .3000 inch, maximum .3005 inch. Minimum diameter of groove is .3080 inch, maximum .3085 inch. The variation in diameter of bore and groove in each individual rifle must not exceed one ten-thousandth of an inch.

The chamber and bullet seat entrance are as near minimum as possible to insure the bullet starting true in the bore. Care has been exercised in the manufacture of barrels to reduce the amount of straightening to a minimum. The receiver is machined from special double heat treated Class "C" steeel, and the bolt runways and cam surfaces polished to insure a smooth working bolt. Special care has been taken in assembly of barrel and receiver to see that the well hole of the receiver is in line with the bore.

The bolt is specially double heat-treated of Class "C" steel, is polished and the cam surfaces burnished by hand, with head space held to minimum dimensions. The firing pin is minimum to prevent punctures and pulling of primers with any type of ammunition. The main spring is carefully gauged and tested to pull from 16½ to 19 pounds after compression for 36 hours. The stocks are made from selected walnut and machined with special care so that the barrel and receiver will bed properly. The upper and lower bands are loose enough to be put on by hand so as to prevent undue strain and allow the proper vibration of the barrel. The stock after machining is soaked four times in linseed oil and dried from two to four hours. The rear sight is assembled with great care to eliminate lost motion, looseness and bacl lash. All rifles are fitted with drift slides having .06 aperture. One size smaller and one size larger are available for each rifle. The front sight is specially machined on top so as to be square and true with the sides. The trigger has a grooved finger-piece to prevent slipping. The sear nose is slightly shortened and carefully stoned by experts to insure release. The sear notch is carefully ground.

The trigger pull is adjusted from 3½ to 4½ pounds and must be smooth without creep. The butt plate is checked for the purpose of insuring a firm seat at the shoulder when firing.

Inspection and Test: The assembled rifle is given a rigid inspection by the most expert inspectors of the Armory. One proof charge developing 75,000 pounds pressure per square inch is fired and in addition 25 rounds of service ammunition are fired to settle the action in the stock and test the action for smoothness of operation.

The bolt lift is controlled by the careful gauging of parts and stoning cam surfaces, so that the pull-up of the bolt does not exceed 15 pounds.

The rifle is targeted for accuracy by expert riflemen at 200 yards, muzzle and elbow rests are used. Sights are first adjusted by firing at an inverted T (1) target measuring 4 niches horizontally and vertically. The front sight must not be offset more than .015. Aim is taken at the bottom of the inverted T (1) with just a line of white. With sights properly adjusted to zero, 5 rounds are fired. If all five shots are in the vertical strip and do not measure more than 8 inches vertically the rifle is accepted, provided it does not show a tendency to walk. The rifles are inspected again after firing, the bore cleaned in the usual way and metal parts coated with cosmic. The rifles are then packed in arm chests. With each rifle is the target made with the rifle and a card giving the interior dimensions of bore and groove for each inch of the barrel.

Ammunition: Frankford Arsenal, 1921 National Match ammunition, with tin coated bullets, has been used in testing the rifles and has demonstrated the proper functioning of 1921 National Match Rifles with 1921 National Match Ammunition. Smoothness of action with minimum pull in ex-

Continued on page 118.

Ordnance Work at Tank Center

From the standpoint of mechanical equipment with combat troops one of the most interesting of field service activities, the magnitude of which is generally little appreciated, is in connection with the Tank Center at Camp Meade, Md. Here are concentrated all tank training, the Army tank reserve and practically all tank material and armament except that in the hands of divisional troops. The tank schools and the Army tank reserve comprise slightly more than 2,000 troops actively engaged in training. Of the larger items of equipment there are on hand at Camp Meade with troops and in the hands of the Ordnance officer approximately 600 American built six-ton tanks, 200 Renault (French) tanks, 100 Mark VIII tanks and 20 British (35-ton) tanks with accompanying armament consisting of six-pounder, 37 mm. and machine guns.

A considerable part of the tank equipment returned from overseas after the armistice was, due to conditions beyond control, received in damaged, rusty and unserviceable condition. Much of the material in process of manufacture at the signing of the armistice was taken and shipped as partially completed. To properly condition this material and provide the combat arm with satisfactory equipment for training and action presented a serious problem. It was decided to accomplish this work at the Franklin Cantonment, Camp Meade, Md., and something more than a year ago a heavy mobile ordnance repair shop, with certain additions in the way of personnel and equipment made necessary by the nature of the problem at hand, was attached to the Tank Center. Since that time the work of overhauling and rebuilding has progressed continuously together with the normal maintenance and repair of tanks and armament in service. In the month of January, 1921, eighty-four six-ton American built tanks were overhauled, repaired and minor modifications installed; in February, 62 American built tanks passed through the shops for overhaul, repair and installation of modifications; in March, 77 six-ton American built tanks were overhauled, repaired and modifications installed; a total of 223 six-ton American built tanks passed through the shops during the quarter, or an average of three and a fraction per working day.

In addition to this work in the month of March 10 French tanks were completely disassembled, passed through inspection and usable parts placed in stock for use in overhauling and rebuilding 100 French tanks; also seven British tanks were put in operating condition, cleaned, oiled and tracks repaired, six-pounder guns dismounted, sponsons drawn in, and tanks checked. During this period there was undertaken in the shop a considerable amount of special machine work, such as the manufacture of special firing pins for six-pounder guns; the manufacture of 1,009 knurled set screws for machine gun tank mounts; repairs to farm implements; repairs to blueprinting machines; special bolts, spikes, wrenches, bushings, studs, etc. Devices such as jigs for loading and unloading six-pounder and 37 mm. ammunition were manufactured and a number of sub-caliber barrels for six-pounder and 37 mm. guns were made and adjusted for the tank schools. Many of the smaller modifications for the American built tanks have been manufactured in the local shops and more than 100 shields for ball mounts were cut and fitted. All machine tool equipment has been overhauled, repaired, parts manufactured and installed and the motor generator sets and transportation equipment belonging to the 1st Heavy Mobile Ordnance Repair Shop has been overhauled.

In January, 1921, upon orders issued by the Ordnance office, the Ordnance officer at Camp Meade took over from the Tank Center supply officer all Ordnance material not in hands of troops, consisting of tanks, tank armament, trucks, tractors, trailers, spare parts, accessories and supplies. This material was stored in warehouses, it requiring approximately 48 buildings to accommodate all of the material. There are no more important duties in connection with the operation of an army than the proper maintenance of its equipment and the foregoing will give some idea of the quantity of work attached to the average Ordnance repair shop. These shops in the A.E.F. were the objects of complimentary commendations by officers of the Allied armies and a larger percentage of the equipment of the U. S. Army was kept in actual service than that of any of the Allied armies.

Track Losses in Track-Laying Vehicles

The Ordnance Department has recently been making extensive studies of the best design of tracks for the track-laying or caterpillar types of vehicles, such as artillery tractors and tanks, and in this connection has made numerous tests to determine the power losses in such tracks and the effect of lubrication on these losses.

While these vehicles are in a measure similar to farm or industrial tractors, they are required to travel at much greater speeds, and one of the principal problems encountered has been the excessive consumption of power in present tracks at high speed. In the early development of track-laying vehicles, little attention was paid to either the lubrication of the tracks or other losses of power therein, and the experiments have shown that this practice was justified as at three miles per hour losses due to lack of lubrication were found to be only 1 per cent of the power developed by the engine and other losses 3 per cent.

How serious this question becomes from a military standpoint, where high speed is demanded, is, however, shown by the fact that at ten miles per hour track losses were found to be as high as 16 per cent, 7 per cent being due to poor lubrication and 9 per cent due to other losses; while at 16 miles per hour total losses ran as high as 36 per cent 15 per cent being due to poor lubrication and 21 per cent due to other losses.

With the present types of metal tracks, which are built of steel links connected together with pins, it has been found that the best method of lubricating in the field is to slush the tracks with a swab similar to that used for oiling railway

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Small Arms Division Notes—Continued

tracting has resulted. Remarkable accuracy has been obtained.

Owing to the smoothness of the bore of barrels and the tin coated bullets used, no fouling has been found in the bore that could not be removed with a scratch brush and proper cleaning.

The use of grease on bullets or cartridge cases is undesirable. The rifle is amply strong to withstand the pressure of the 1921 ammunition, but if grease is used the pressure is concentrated on the bolthead by the slipping of the case. If the case is a little soft it may give way and allow an escape of gas that will seriously injure the shooter.

When cleaning the rifle it should not be disassembled except the bolt and floor plate; to do so will probably change the zero of the rifle and will destroy the accuracy of the rifle if it is not bedded again in the stock properly. The guard screws should be kept tight at all times. The bolt should be washed with gasoline, inside and out, and no oil or grease left on the inside of the bolt or on the firing pin.

The rifle should be cleaned not later than the evening of the day it is used.

First. A wire brush, preferably a steel wire brush, should be run through the bore several times to loosen the fouling caked in the bore. This is most noticeable at the muzzle end.

Second. Swab the bore thoroughly with flannel patches soaked with any satisfactory rifle cleaner or oil.

Third. Scrub the bore until perfectly dry and clean with dry flannel patch.

Fourth. Swab the bore thoroughly with a patch wet with cosmic.

The above cleaning should be repeated in twenty-four hours, if the rifle is not used.

The 1921 National Match Rifles have shown such satisfactory results in all accuracy and functioning tests that full confidence can be placed in them.

switches and curves. Experiments are being made with hollow track shoes filled with oil and with a system of manual lubrication applied to each track pin, but whether any very satisfactory lubrication system for the present types of tracks will be developed is doubtful.

The track losses other than those due to lack of lubrication, which run as high as 21 per cent, can be decreased to a limited extent in present designs by lightening the track, but the total saving that can be realized by this means is not satisfactory, and the conclusion has been reached that the only thoroughly satisfactory means of largely eliminating the total losses will be found in a completely new design of track in which the numerous wearing surfaces and the great weight of the present link and pin construction is eliminated.

Preliminary tests of tracks made largely of fabric belting and weighing only one-third as much as the conventional track have been very successful on small vehicles, and the construction of somewhat similar experimental tracks made of steel cables to which are attached suitable shoes for contact with the ground have been started for larger vehicles.

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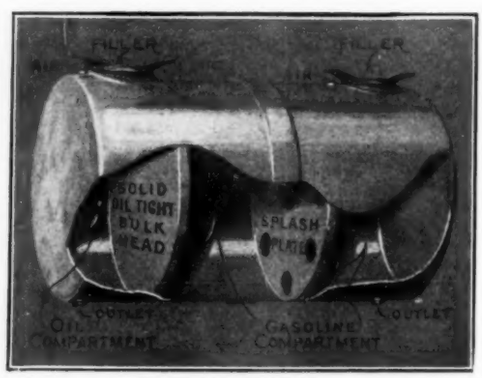

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